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Note-taking and the decision to externalize memory

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Note-taking and the decision to externalize memory

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessibly and will not permit alterations after a degree is conferred

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ABSTRACT

The purpose of this dissertation was to examine the relationship between note-taking and learning, particularly as it relates to the use of technology in the classroom. Two laboratory studies explore how taking and saving notes on a computer impacts memory for facts and the folders where notes for those facts are stored. A qualitative study provided an updated look at how students think about note-taking and how technology affects their note-taking habits. Another laboratory study explored the difference in recall for facts and folders when notes were taken by hand on note-cards and saved in physical folders or on a computer and saved in digital folders. The first two studies found that the act of choosing where to save notes improved memory for folders while decreasing memory for difficult facts. These results held true regardless of whether participants believed they would be able to use their notes. The qualitative study found that 10 out of the 14 students who were interviewed emphasized the process rather than the product of note-taking and most interviewed students (12 out of 14) altered their note-taking behavior if instructors posted lecture slides online. The final study found that memory for facts and folders was marginally better for participants who handwrote their notes but it may be because they spent more time completing the task.

CHAPTER 1. INTRODUCTION

Laptop computers are a common sight in college classrooms. Even when not serving a vital course function, students use their computers during class for a variety of tasks, both relevant and irrelevant (Fried, 2008; Kay & Lauricella, 2011; Sana, Weston, & Cepeda, 2013). When laptop usage is not built into a curriculum, students might use their laptops for activities that distract them from learning such as checking emails, chatting with friends, or looking at unrelated content (e.g., Fried, Ravizza, Utivlugt, & Fenn, 2017). Among the relevant tasks, according to a large survey (Kay & Lauricella, 2011), the most prominent activity is note-taking.

Because it is such a common educational practice, note-taking behavior has been the subject of many laboratory studies over the years (for a recent review, see Jansen, Lekens, and IJsselsteijn, 2017; for an earlier review, see Kiewra, 1989). A recent trend in note-taking research has focused on comparing the effects of handwriting or typing notes on learning (Beck, Hartley, Hustedde, & Felsberg, 2014; Bui, Myerson, & Hale, 2013; Mueller & Oppenheimer, 2014; Mueller & Oppenheimer, 2016), often with mixed results.

Two recent studies that compare handwritten and typed notes illustrate the inconsistent findings in this area. Bui et al. (2013) measured memory for facts and discovered that participants who used laptops to take notes performed better on an immediate recall test than those who took notes by hand. Mueller and Oppenheimer (2014) used a similar paradigm to measure both factual memory and conceptual understanding. Their results indicated that participants who took notes by hand or by laptop performed equally well on factual questions, but participants who took notes by hand performed better on questions of conceptual understanding and application. Drawing conclusions from these conflicting results is difficult. How well participants perform on a given test seems to depend on how well suited their note-taking platform is to the content being tested. In the case of Bui et al. (2013), laptops were better suited for making note of as much information as possible, which benefited participants taking a recall test. In the Mueller and Oppenheimer study, handwritten notes were better suited for conceptual questions because writing by hand imposes a limit on the amount of information that can be noted, which the authors argued led to more conceptual processing during note-taking.

Given the uneven results from comparisons of handwritten and typed notes, there is a need for a more in-depth analysis of the processes underlying note-taking behavior. The focus of this dissertation is how computer access has impacted the note-taking process as it relates to internal and external memory storage. While much of the research on note-taking emphasizes the process by which taking notes facilitates encoding information in memory (e.g., Jansen et al., 2017), little emphasis has been placed on the impact of information technologies, such as laptop computers, on this process. To that end, this dissertation seeks to elucidate the effect that digital information storage has on internal human memory, to update an older theory of note-taking to include the impact of modern technologies, and to provide an in-depth look at the encoding process when comparing handwritten and computer-generated notes.

The first part of this dissertation provides an overview of the theoretical frameworks within which the research studies are situated. This overview includes a description of the depth-of-processing framework of memory, prominent theories of note taking, several hypotheses that explain metacognitive strategies, an outline of cognitive offloading as it relates to note-taking, a dominant theory of the limited capacity of working memory, and finally, a quick primer on how difficulty relates to judgments of learning. Following this overview are three research articles. The first provides an in-depth look at the impacts of computerized note-taking on memory for facts and where to find notes about them. The second describes a qualitative study of how technology affects note-taking from the perspective of students. The third describes a mixed method study comparing handwritten and computerized note-taking.

Memory and Depth of Processing

In order to understand the note-taking process and the impact that modern technologies have had on human cognition, it is important to describe the model of human memory that is assumed in the subsequently described research. Memory has long been studied by cognitive psychology researchers. Numerous models of memory have emerged with a convergence on the existence of three levels of storage: sensory memory, short-term or working memory (STM), and long-term memory (LTM) (e.g., Atkinson & Shiffrin, 1968; Murdock, 1967). Craik and Lockhart (1972) proposed an alternative framework, which arguably just expanded upon the modal model (Healy & McNamara, 1996), that focused on the depth at which information is processed. Through a series of ten experiments, Craik and Tulving (1975) showed that information which is processed with more effort is more likely to be recalled than information that is more superficially processed. Participants in these studies were briefly shown common nouns, one at a time. Prior to seeing each word, they were given a question that they had to answer about the word as quickly as they could upon seeing it. The questions that required more effortful processing asked participants either to determine whether the word fit into a particular category or if it would fit into a particular sentence. This level of processing required participants to consider the meaning of the word, which

Craik and Tulving argued would lead to a deeper encoding and a stronger memory trace for that word. Questions that required less effortful processing were generally about shallow or more superficial characteristics of the word such as whether the word was presented in capital letters. The finding that more effortful processing produced better memory made a very compelling argument was made for focusing on the process of encoding when considering whether or not something has been learned.

One of the primary foci of this dissertation is the effort involved in encoding different types of information. Some of this work is motivated by a study that examined the effect that easy access to Internet search engines is having on memory (Sparrow, Liu, & Wegner, 2011). Sparrow et al. argued that having access to a search engine made it possible for participants to rely on remembering how to find information rather than trying to remember the information itself. In order to test this hypothesis in a more controlled environment than would be possible if they used an Internet search engine, participants were asked to type trivia sentences into a computer where some of the sentences would be saved in folders with generic names (e.g., FACTs, DATA, INFO). Participants were lead to believe they would be able to access the saved statements during a subsequent test if they correctly remembered where they were saved. After concluding this study phase, participants were given a free recall test wherein they were asked to list as many of the statements as they could remember in 10 minutes. They were then shown cues associated with each statement and asked if they could remember where that statement had been saved. The results were that participants recalled more of where statements were saved than they recalled the statements themselves.

Although Sparrow et al. (2011) argued that the results were indicative of participants' preference for encoding where they could find information, there is a potential problem.

Participants were asked to type into a compute ra set of statements provided on a sheet of paper. It is possible that participants did not engage in effortful processing of the statements as they typed the statements into the computer. Taking verbatim notes by simply copying a text word for word has been associated with a shallow level of processing for the information, which would lead to poor encoding and recall (Bobrow, Bower, & Grant, 1969; Bretzing & Kulhavy, 1979). Thus, the poor memory for the statements may have been the result of shallow processing rather than a focus on where the statement was stored.

Within the note-taking literature, some have employed the depth-of-processing framework to understanding the efficacy of different types of note-taking strategies (e.g., Bohay, Blakely, Tamplin, & Radvansky, 2011; Kiewra, 1988; Kiewra, 1991; Weinstein & Mayer, 1985). In Chapter 2 of this dissertation, participant note-quality is examined in relationship to their memory for facts as well as their apparent willingness to rely on their notes instead of internal memory. In Chapter 4, note quality is compared between handwritten and typed notes. Before describing the dominant theories of note-taking as they relate to learning and memory, the following is a brief description of the limitations of working memory and why it might be necessary to choose which information to store internally.

The Capacity Limit of Working Memory

Working memory has been described as a system (or systems) that maintains information while a variety of cognitive processes are being performed (e.g., Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Baddeley, 2010). Working memory has a limited capacity such that not all information that is available for processing can actually be processed at a given time. Several explanations have been put forth as to what limits working memory capacity, but in their review on working memory capacity limits Oberauer, Farrell, Jarrold, and Lewandowsky (2016) determined that the dominant theory (i.e., the one that fits the most observable phenomena) is that interference between different bits of information is the limiting factor. Humans can hold multiple representations of information in mind at the same time but they interfere with each other. The possibility of interference is directly relevant to the study by Sparrow et al. (2011) on what information people remember when they have information saved on a computer and know where to find it. Sparrow et al. made a direct comparison between memory for trivia statements and memory for where on a computer those statements were saved. This comparison only makes sense in the context of a limited working memory capacity, and it fits with the interference model in that both facts and the names of folders were presented as written words that entered working memory in the same context. Because participants were limited in the amount of information that could be processed into internal memory, they may have considered the availability of an external record when choosing what information to process (i.e., what information to store internally).

As will be described in the next section, the need to develop a way to handle the limitations of working memory is related to note-taking. In fact, the creation of an external memory record to supplement internal memory is one of the two dominant theories of note-taking.

Theories of Note-Taking: Encoding and Storage

The two prominent explanations of the benefits of note-taking have been described as the encoding hypothesis and the external storage hypothesis (Di Vesta & Gray, 1972). While the encoding hypothesis of note-taking focuses on the benefits of note-taking derived from the process of note-taking, external storage focuses more on the product. While the two are not mutually exclusive, older note-taking research studies have pitted the two against each other (e.g., Kiewra et al., 1991; Rickards & Friedman, 1978). Within this work, the two hypotheses are treated as complementary. Encoding is about the information that is stored in internal memory while external storage is about how the existence of external memory interacts with what is stored in internal memory. The external storage hypothesis, which posits that the benefits of note-taking lie predominantly in being able to later have access to the information covered in lecture. It will be described in more detail later when it is considered in terms of its relationship to a process called cognitive offloading. The encoding hypothesis will be described here as it relates to effortful processing.

According to the encoding hypothesis, note-taking facilitates learning because the process of recording information can facilitate encoding. Numerous studies have examined the encoding hypothesis of note-taking by comparing the recall performance of participants who watched a lecture and took notes to that of participants who watched the same lecture and did not take notes. A meta-analysis of the encoding-effect of note-taking found a medium effect of note-taking itself (i.e., without subsequent study of the notes) on free and cued recall, and a small-to-medium effect on recognition and higher-order performance tests (Kobayashi, 2005). The varied results from the studies described in the meta-analysis suggested a need for further elaboration on the cognitive processes underlying the encoding benefit of note-taking.

The encoding benefit of note-taking seems to derive from what has been referred to as the generation effect (Peper & Mayer, 1978; Peper & Mayer, 1986). The generation effect is that the act of relating new materials to previously existing knowledge involves deeper processing than simply copying information down without thinking about it, and this deeper processing leads to better understanding of the information. Other explanations of the encoding benefit of note-taking include the attention hypothesis, which states that the act of note-taking forces students to attend to the lecture. The distraction hypothesis, which states that the physical act of writing down notes requires focus and actually distracts the note-taker from listening to the lecture, highlights a potential detriment to the note-taking process, which may detract from the encoding benefits. Peper and Mayer (1986) found no support for either hypothesis, but a theory of note-taking based on college student perceptions (Van Meter, Yokoi, & Pressley, 1994) included the attention-directing effect. As will be seen, there also is support for both attention-directing and distraction in the qualitative study described in Chapter 3.

In summary, the encoding effect of note-taking seems to be based predominantly on the type of cognitive processes that are engaged during note-taking. Taking notes verbatim, which entails copying information without transforming it in any way, does not require engaging in deep processing of information, and has been associated with poor learning outcomes (e.g., Bretzing & Kulhavy, 1979; Kiewra, 1989; Kobayashi, 2005; Igo, Bruning, & McCrudden, 2005; Mueller & Oppenheimer, 2014). Engaging in more generative processes while taking notes entails a deep processing of information, which previous research suggests leads to better learning of the information (Kobayashi, 2005; Mueller & Oppenheimer, 2014; Peper & Mayer, 1986; Piolat, Olive, & Kellog, 2005). Laptops facilitate verbatim note-taking because they allow for faster note generation (e.g., Bui et al., 2013; Mueller & Oppenheimer, 2014), but the process of deciding what information to include and how much effort is put into encoding that information complicates this interaction. The metacognitive strategies that could be engaged during note-taking and how one might decide whether to encode certain information or to simply transfer it to an external storage device for future encoding are described in the next section.

Metacognitive Strategies

Metacognition generally refers to the processes by which individuals reflect upon their cognitive processes and how they put this self-reflection to use in order to regulate their behaviors (Koriat, 2007). Having a solid understanding of one's own learning and being able to determine when something has been learned or when it needs further study can be helpful for developing effective study strategies (e.g., Karpicke, 2009). Unfortunately, when left to their own devices, students do not seem to engage in the learning strategies that researchers have determined to be most effective (Karpicke, Butler, & Roediger, 2009). For instance, researchers have, time and again, demonstrated that self-testing is a more effective strategy for successfully encoding material than restudying (for a review, see Rowland, 2014). Karpicke (2009) examined the strategies participants chose to use when given the opportunity to either restudy or test themselves on word pairs that they were learning. He also had participants provide judgments of learning (JOLs) to indicate how confident they were that they had learned each pair before they chose whether to restudy it, drop it, or be tested on it as part of their next study opportunity. He found that, based on their JOLs, participants had set higher thresholds for when they would be tested on an item than when they would choose to restudy it. That is, participants had to be more confident that they would recall an item before they wanted to be tested on it, opting instead to restudy any items they were not confident in having learned. Aside from finding that participants were not utilizing the most effective study methods, Karpicke was able to demonstrate an association between participants JOLs and their willingness to try to relearn something (even though their strategies for doing so were misguided). This finding is important in understanding the way that technology might impact the metacognitive strategies that students use when learning.

Ferguson, Mclean, and Risko (2015) examined the influence that having access to the Internet might have on metacognitive processes. In one within-subjects experiment they presented participants with general knowledge questions of varying levels of difficulty. For half of the trials participants were allowed to look the answers up on the Internet if they responded that they did not know the answers offhand. For the other half of trials, participants either responded that they did not know the answer and moved on or provided an answer that they did know. The results showed that when participants were given Internet access, they were more reluctant to volunteer answers, opting instead to look them up online. A second experiment assessed participants' feelings of knowing when completing a similar procedure to the first experiment. Participants who experienced the Internet condition first had lower overall feelings-of-knowing, which the authors interpreted as an Internet-related reduction in feelings-of-knowing. Ferguson et al. concluded that participants might want to be more confident in knowing the answers before responding when they could look these answers up online. That is, when participants had access to an external knowledge repository, they seemingly judged their internal knowledge as less accurate. Instead of trying to recall the answers to questions in which participants were not especially confident, which might help them learn the answers better so they could develop more confidence, participants opted to look-up the answers when they were available. Technology, in this case, seems to have provided a restudy option.

In summary, at least some metacognitive judgments about what enhances memory are misguided. Karpicke (2009) found that participants were more reluctant to test themselves on information they were not confident that they had learned. Ferguson et al. (2015) found that having access to the Internet seemingly made their participants more reluctant to volunteer information even when they may have known it. A more nuanced examination of when one may decide to rely on an external resource in lieu of a cognitive process entails a discussion of two explanations of how the decision to externalize cognition is made: the dual process perspective, and the soft constraints hypothesis.

Dual-process theories of higher cognition

One explanation for why one might be disinclined to rely on internal cognitive resources is that humans are cognitive misers (e.g., Kahneman, 2011; Stanovich, 2009). Being a cognitive miser entails the tendency to choose an easy answer reflecting the readily available information one is presented rather than using the information to try to make inferences that may take more effort. This view assumes that there are two underlying types of processing and that one occurs more rapidly and takes less effort than the other. Evans and Stanovich (2011), in responding to critics of dual-process theories, provide a robust explanation for what the two processes are. Type 1 processes do not require much effort in terms of control processes and working memory resources. One does not have to think very hard when engaging in Type 1 processes, which occur quickly and automatically. Type 2 processes, on the other hand, seem to make larger demands on working memory and the ability to engage in cognitive decoupling, which entails separating a belief about the world from the world that is being represented by the belief (Stanovich, 2006). There may be a bias towards relying on Type 1 processes because there seem to be some positive feelings associated with the ease with which information is accessed (e.g., Alter & Oppenheimer, 2009; Briñol, Petty, & Tormala, 2006). That ease, may in turn lead to inflated feelings of confidence, which can be reflected in JOLs (Hertzog, Dunlosky, Robinson, & Kidder, 2003). One can conclude, therefore, that people may opt for using their own knowledge when they feel confident in it but choose to rely on easily accessed external resources when they do not.

The soft constraints hypothesis

Dual-process theories of higher cognition are useful for understanding how information may be processed when making decisions, but do not necessarily explain how the decision are actually made. One explanation for how decisions regarding the completion of a task are made is referred to as the soft constraints hypothesis (Gray, Sims, Fu, & Schoelles, 2006). The soft constraints hypothesis states that there is not a simple rule for determining whether one would complete a task mentally using memory resources or rely on an external resource when possible. Instead of always opting to minimize working memory load (i.e., instead of describing humans as cognitive misers), the hypothesis states that processes are selected (either cognitive or motor) with the goal of minimizing performance cost, which is measured in time, while still achieving expected benefits. That is, when performing a task, one generally will choose whichever method seems to be faster while still achieving the same outcome. In order to test this hypothesis in comparison to the hypotheses that people always do whatever minimizes working memory load, Gray et al. (2006) conducted a series of experiments. In each experiment participants were given the task of arranging, on a grid, some different colored blocks. They were provided with a target arrangement, an area where they could grab the virtual blocks (the experiments were done on a computer) and an area where each block could be dragged and dropped into an area on the grid. Throughout three experiments, participants experienced different conditions under which the target window could be accessed. Sometimes accessing the window required pressing a key, while other times it entailed dragging the mouse over the target window and waiting for a few seconds before the target arrangement appeared. The results for each experiment indicated that when it was easy and took less time to access the target window, participants made more frequent usage of the window and spent less time looking at it the first time they used it. When it was difficult or time consuming to use the window, participants spent more time looking at the target the first time they accessed it and subsequently accessed it fewer times. The authors suggested that these results support the idea that people will use their own memory stores when it seems to take less effort and rely on external resources when that seems to take less effort.

Based on the idea put forth by these explanations, one may postulate that when a student is learning, he or she may rely on internal cognition when the content seems relatively easy to learn and may engage with an external resource when the content seems difficult. Within the context of note-taking, students may choose to write down information that is difficult to remember in order to have a record of the information that they could reference in the future. If the student is a proficient typist, noting this information might not require much cognitive effort and could be fully offloaded to the motor-system responsible for typing. If information seems relatively easy to learn, the student may choose to forgo writing the information down in its full form but may jot down a keyword that may assist in mentally encoding the information. In order to situate the aforementioned metacognitive strategies in the context of technology usage, the following is a description of cognitive offloading.

Cognitive Offloading

Cognitive offloading describes the use of a physical action, either an interaction with an external resource or a body movement, that serves to reduce the cognitive demand of a particular task (for review, see Risko & Gilbert, 2016). A physical action aids cognition by transforming a task that could be completed mentally, such as basic arithmetic, into a motor-task, such as pushing buttons on a calculator. Research comparing the benefits of using a calculator to do arithmetic to doing mental arithmetic found that self-generating answers by doing mental computations lead to better learning of arithmetic (Pyke & LeFevre, 2011). When the task is too complex to be done mentally, such as calculus, using a calculator can benefit learning by allowing students to focus on conceptual understanding rather than taxing their memory with complex procedural information (e.g., Leng, 2011). When considering the type of task that should be offloaded from using mental resources to relying on physical ones, it is reasonable to conclude that simple tasks should be completed mentally while more complex tasks would benefit from offloading.

A recent study of cognitive offloading related to a short-term memory task indicated that participants came to a surprisingly different conclusion (Risko & Dunn, 2015). Over the course of two experiments, Risko and Dunn (2015) discovered that almost 40% of their participants chose to offload memory when they were asked to keep two letters in mind for immediate recall, and that this decision was mostly based on how unreliable participants found their internal memory relative to external storage. Similarly, in deciding whether or not to rotate their heads to read tilted text, participants in a series of four experiments based their decisions, according to the researchers, predominantly on subjective judgments of effort and performance benefits rather than more objective measurements of effort and performance

(Dunn & Risko, 2016). The decision to offload, therefore, is not as straightforward as it seems.

Given the apparent complexity of the decision to offload, it is important to consider how the perceived difficulty of an item affects the decision of whether to offload information onto external memory storage or rely on internal memory. The following is a brief description of the fluency effect and perceived difficulty.

Difficulty and the Fluency Effect

In Chapters 2 and 4 of this dissertation, participants were tasked with remembering both easy and hard facts. The rather intuitive idea that some facts might be easier or hard to remember than others comes from the metacognitive experience of processing fluency. Processing fluency refers to how easily information seems to be processed by the individual who is processing it (see Alter & Oppenheimer, 2009 for a review of the fluency effect and more on processing fluency). How easy or difficult it is to process something seems to impact participants' judgments of how well they have learned that thing (e.g., Dunlosky & Metcalfe, 2008). If an item is judged to be very easy, a student learning that item might be overconfident in their ability to remember it and not devote as much time or effort to trying to learn it (see Finn & Tauber, 2015 for a review of how fluency can lead to overconfidence and less effort in learning). The fluency effect describes this phenomenon of judging something to be easy to learn and not devoting as much effort to learning it. When information is perceived to be difficult to remember, however, one might look for alternative methods of learning that information such as by relying on an external source (e.g., Dunn, Lutes, & Risko, 2016). In Chapter 4 of this dissertation, participants were asked to make judgments of how difficult they found each fact to be. It was expected that participants would rely more on internal memory for facts that were deemed easy, due to processing fluency and confidence, and to rely more on using their notes for facts that were considered hard.

Overall, an understanding of the impact that technology has on learning vis-à-vis the note-taking process has a few theoretical components and methodological constructs. An understanding of the depth-of-processing framework of memory provides background for examining how students might learn information. The encoding and storage hypotheses of note-taking provide a useful skeleton for understanding how students might process information as they learn. Metacognitive strategies provide possible explanation for how decisions are made whether to process information entirely internally or rely on an external resource. Cognitive offloading gives context to those strategies. Finally, in order to examine the cognitive processes involved in a task that pits internal memory against external storage, it helps to have some knowledge of whether participants' perceptions of difficulty impacted what information they stored in internal memory and whether the method of note-taking (handwritten or typed) affected what information participants chose to focus on remembering.

Introducing Three Studies

Three studies are described in this dissertation that together try to address the way that students take notes and how they use them to learn in the current climate of information technologies. The structure and relationships between the studies is shown in *Figure 1*.

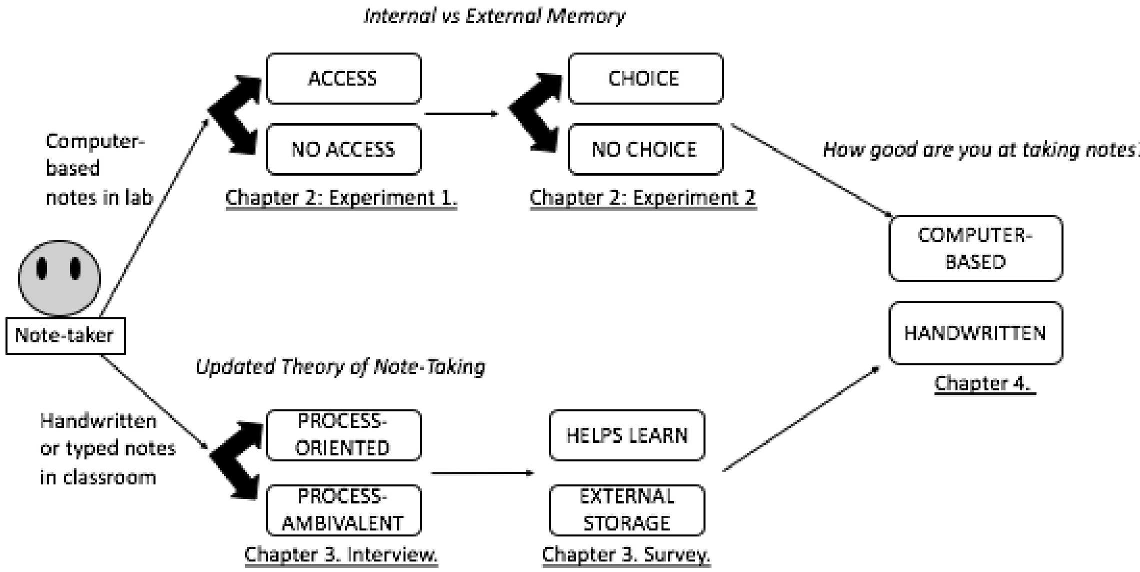

Figure 1. The three studies of the dissertation. Chapter 2 includes 2 quantitative experiments, Chapter 3 includes semi-structured interviews and a survey. Chapter 4 includes a quantitative experiment with a qualitative component.

The first study, in Chapter 2, includes two laboratory experiments that examine how taking and saving notes on a computer affects what information is stored internally. Experiment 1 asked if participants' beliefs about whether they would be able to access their notes during a recall test would impact whether they remember the information they studied or the names of the folders where they saved that information. The second experiment in Chapter 2 asked if being allowed to choose where information would be saved impacted whether a participant would focus on the information they studied or where they had saved it. It tested the hypothesis that having access to a computer-based external memory would change the encoding process such that being able to find information stored externally would take priority over storing that information internally.

The second study, described in Chapter 3, is qualitative in nature and sought to align the findings of the laboratory studies with the lived experiences of college students. The Experiments of Chapter 2 relied on the assumption that the process of note-taking was important to students and would affect their learning. Structured interviews were conducted with undergraduate students to examine student perceptions of note-taking, what they see as important and how technology used in the classroom impacts their note-taking habits. Chapter 3 also includes a survey that more broadly contextualizes the data from the interviews.

The third study, in Chapter 4, is a mix of quantitative and qualitative methods. The laboratory experiment in this study used methods similar to the experiments in the first study, but compared computerized note-taking with handwritten note-taking. Judgments of item difficulty were included to examine how item difficulty related to memory for facts and where to find their notes for them. Chapter 4 expanded upon the findings of Chapter 2 and was informed by the findings of Chapter 3.

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CHAPTER 2: INTERNAL VS EXTERNAL MEMORY

Abstract

Laptops are a common sight in higher education classrooms. Few have looked at how laptops, when appropriately used for note-taking, affect learning. Sparrow, Liu, and Wegner (2011) found that when information is saved on a computer, people often do not remember the information but remember where it is saved. This research further explored the phenomenon by examining how belief about information availability and the ability to choose where information is saved affect memory. Experiment 1 examined whether the belief that at time of test one will have access to information stored in an electronic folder if the name of the folder is known affects whether the information is remembered or whether the folder in which it is stored is remembered or both. Belief did not impact what information was remembered, but memory was better for where difficult information was stored than it was for the information itself. Experiment 2 investigated whether the act of choosing where to store information led to better memory for the chosen folders and if so, whether that influenced memory for the facts. Participants who chose their folders remembered more folders, and participants who did not choose remembered more facts. There may be a tradeoff between memory for information and memory for where to find it.

Laptop computers are a common sight in college classrooms. When laptops are allowed in class, the most frequent class-relevant activity students use them for in is note-taking, but laptops also make it easier for students to engage in distracting activities, which some studies indicate occurs the majority of class-time in large lecture classes (e.g., Kay & Lauricella, 2011; Ragan, Jennings, Massey, & Doolittle, 2014; Ravizza, Utivlugt, & Fenn, 2017). When deciding whether to allow students to use their laptops in classes that do not integrate computer usage into the curriculum, instructors need to consider the impact that using a laptop computer may have on learning. Aside from considerations of distractibility and the negative impacts that laptop usage has been shown to have on class performance (e.g., Fried, 2008; Ravizza et al., 2017), it is also important to investigate how taking and storing notes on a computer affects learning. The purpose of this study is to examine what information is remembered when someone types and saves notes on a computer.

Many researchers have investigated the process of classroom note-taking as it relates to the retention of information for the purpose of test-taking (for a recent review, see Jansen, Lekens, and IJsselsteijn, 2017; for an earlier review, see Kiewra, 1989). Most have focused on handwritten note-taking because widely available portable computers did not exist in the 1970s and 1980s when much of the research on note-taking took place. The primary focus of much of this research was on two theories of how note-taking can be beneficial to learning, which were described by Di Vesta and Gray (1972): encoding and external storage. The encoding theory of note-taking stated that students benefit from the *process* of note-taking because it facilitates encoding. In contrast, the external storage theory stated that the student benefits from using the notes, an external *product* of note-taking, to study or review the material at a later time.

Note-taking studies examining the encoding hypothesis focused on the process of note-taking rather than the product, so participants in these studies generally took notes but did not review them (see Kobayashi, 2005 for a meta-analysis of the encoding theory of note-taking). The encoding theory of note-taking is largely based on the idea that the act of taking notes leads to a deeper level of information processing than would occur when passively receiving information (e.g., Bohay, Blakely, Tamplin, & Radvansky, 2011; Bretzing & Kulhavy, 1979; Kiewra et al., 1991; Piolat, Olive, & Kellogg, 2005). The idea that information could be processed on different levels and that this depth of processing can impact likelihood of recall was introduced by Craik and Lockhart (1972). This levels of processing framework was supported through a series of studies that showed that when participants considered the meanings and semantic associations of words they were learning, they had a greater chance of remembering those words than the words that were considered only in terms of their linguistic structures or physical properties (Craik & Tulving, 1975). When viewed in the context of this framework, the encoding theory of note-taking relies not just on the motor-program of writing or typing letters, but on the mental processing of information that goes along with that action. The actions involved in note-taking differ between handwritten and computer-typed notes. Handwriting involves producing the shape of each letter as it is written, while typing involves pressing a key on a keyboard, which corresponds to a particular letter, but does not require the recreation of its shape (Kiefer & Velay, 2016). Whether or not this distinction contributes to the level of information processing is an open question, but some clues have been provided by research comparing the aforementioned methods of note-taking.

Typing, which has been described as a faster and more efficient way of recording information (e.g., Aragón-Mendizábal, Delgado-Casas, Navarro-Guzmán, Menacho-Jiménez, & Romero-Oliva, 2016; Bohay et al., 2011; Mueller & Oppenheimer, 2014), has been associated with verbatim note-taking, which involves writing down exactly what was read or said without transforming it in any way (Mueller & Oppenheimer, 2014). This verbatim method of note-taking has been shown to lead to less internal information storage (Igo, Bruning, & McCrudden, 2005; Jansen et al., 2017; Kobayashi, 2005). When compared to handwritten notes, typed notes have been shown to include more information (Aragón-Mendizábal et al., 2016; Bui, Myerson, & Hale, 2013), but an important question to answer is what information is actually encoded into a person's memory when he or she types his or her notes. If a student does not review his or her notes, and the benefit derived from note-taking comes from the information that is encoded while the notes are being taken, then the contents of the notes are only important in so far as they relate to what information is encoded in memory.

In contrast to the encoding hypothesis, which focuses on the extent to which the notes aid encoding as they are taken, the external storage theory of note-taking emphasizes the cognitive offloading aspect of note-taking. Cognitive offloading generally involved using physical actions in order to decrease the mental effort required to complete a task (see Risko and Gilbert, 2016 for a review). Cognitive offloading helps deal with the constraint of a limited capacity to working memory (Shiffrin, 1993). Given the limit in how much information can be processed at any given time, one must make a choice of what information to process and what information to let fade from memory. By storing information externally, one can free up the mental resources that would otherwise be taken up by the act of trying to store that information in internal memory (see Oberauer, Farrell, Jarrold, & Lewandowsky, 2016, for a recent review of working memory capacity limits).

Note-taking accomplishes cognitive offloading through the creation of a stable record of the information that students are tasked with learning. That record could then be revisited, which creates another opportunity to learn the information. A lot of research that included the external storage theory made a comparison between the encoding and external storage functions of note-taking. Such studies generally included experimental conditions in which participants took notes and did not study them, took notes and studied them, and sometimes did not take notes but studied the notes of others (Di Vesta & Gray, 1972; Kiewra & Benton, 1988; Kiewra et al., 1991; Rickards & Friedman, 1978).

The external storage theory of note-taking has become part of a broader conversation on the impact that technology such as the Internet has on internal memory. Research on the impact of Internet access on how people view their own memories suggests that the existence of a quick and easy way to find information decreases the confidence that people have in what they know (Fisher, Goddu, & Keil, 2015) and their willingness to search internal memory for knowledge (Ferguson, Mclean, & Risko, 2015). Recently, Sparrow, Liu, and Wegner (2011) suggested that having easy access to digital information has changed the way that people prioritize information storage such that remembering where information is stored (external storage) may be more important than remembering what the information actually is (internal storage). The research described by Sparrow et al. lays the foundation for the present study.

Sparrow et al. (2011) tested participants' memory for trivia facts and where they were saved on a computer. Participants were tasked with typing written trivia facts into a computer; after typing each fact, participants were informed whether or not the typed fact was saved and if it was saved, into which of six folders it had been placed. Participants were led to believe that during a subsequent memory test, they would be able to see the facts they typed, but only if they could remember in which folder on the computer the fact was stored. Sparrow et al. found that when participants were tested on facts they believed had not been saved, their recall was better than for facts they believed had been saved. In addition, participants had better recall for the folders where the saved facts had been saved than they did for the content of those facts. Sparrow et al. concluded that being told that information was saved on a computer led participants to focus more on where to find the information than on the information itself.

The procedure employed by Sparrow et al. (2011) put encoding of facts in direct competition with encoding of folders. If it is indeed the case, as Sparrow et al. argued, that participants selectively encoded where information could be found when they believed that they would be able to access this information during a test, it could be that this belief drove the encoding process in a particular direction. In order to further investigate this claim, an experiment was conducted that involved manipulating participant’s beliefs about access and measuring their recall for information as well as the location of that information.

Experiment 1

Participants in the Sparrow et al. (2011) experiments read statements off of a printed sheet and typed them into a computer, so the situation was different from the situation of taking notes during class. In order to more closely resemble note-taking in the classroom, participants in Experiment 1 listened to audio recordings of factual statements and typed notes about them with the understanding that they would be tested on the facts. They then saved each note in a folder of their choice, choosing one of six folders on the computer that were distinguished only by the name of a color. In order to determine if the belief that one could access the saved information impacts the information encoded in internal memory, some participants were told that they would be able to access their notes if they remembered where they were saved, whereas other participants were told they were in a group that would not be allowed access. Participants in both groups were informed that taking notes would help them organize their thoughts, which would be beneficial regardless of whether or not they were able to access their notes. Based on the conclusions of Sparrow et al., it was hypothesized that participants who believed they would have access to the saved information would remember a higher proportion of folders where they saved information than participants who were told they would not have access. Conversely, it was hypothesized that participants who believed they would not be able to access their notes would recall a higher proportion of facts than participants who believed they would have access. If participants benefit from the encoding aspect of note-taking, they should see a memory benefit just from taking notes, particularly if they do not expend mental effort on trying to remember where their notes were saved. This is because participants who believed they would not be able to use their notes were expected to put more effort into trying to remember the facts they heard because they would have to rely solely on their own internal memory when trying to recall them.

A pilot study showed that some of the trivia statements used by Sparrow et al. (2011) were very memorable and participants consistently recalled a very high proportion of them. Begg, Duft, Lalonde, Melnick, and Sanvito (1989) showed that the easier information is to process, the more confident someone learning that information feels in their memory for it.

So, in order to examine the selective allocation of encoding effort, facts were included in this experiment that were designed to be more difficult to remember (i.e., it was necessary to put effort into encoding these facts). It was hypothesized that if participants felt confident in their memory for easy facts, they would not feel the need to rely on being able to access their notes, so they would not put effort towards encoding the folders in which they stored them. For the more difficult facts, participants were expected to selectively remember the folders in which the notes on them were stored, if they believed they would be able to access them, but not if they believed they would not. At the conclusion of the experiment participants were asked to describe any strategies they had employed in trying to remember where they put their notes.

Method

Participants and design

There were 44 participants (27 females and 17 males) from Iowa State University who completed the study for credit. The average age of the participants was 19.4 years (*SD* = 1.1). Half of the participants were assigned to the access group and half were assigned to the no access group. The access manipulation was the only between-group variable. Two within-group variables were also included: the difficulty of the facts (easy or hard) and the content that was recalled (fact or folder).

Stimuli and materials

Participants completed the task on a computer using a monitor and keyboard throughout the entire task and a pair of headphones to listen to the facts during the study phase of the task. The task was programmed and presented using E-Prime 2.0 software

(Psychology Software Tools, Pittsburgh, PA). Participants were provided with written instructions presented in black font centered on a white background on the computer monitor.

Stimuli were 36 trivia facts, some taken from Sparrow et al. (2011) and others gathered using the random function in Wikipedia. Prior to the experiment, seven undergraduate researcher assistants judged 48 facts on how memorable and interesting they were. Based on the average ratings, facts were given composite scores for interest and memorability. The 18 facts judged as most interesting and memorable were included as easy facts. An example of an easy fact is “the king of hearts is the only king without a moustache.” The 18 facts rated the least interesting and least memorable were included as the difficult facts. An example of a difficult fact is “Korsakoff’s syndrome occurs as a result of thiamine deficiency.” The higher difficulty facts included topic-specific vocabulary that might not have been familiar to the participants such as “furlong,” “numismatics,” “hermeneutics,” and “Tardive dyskinesia.” All 36 facts are provided in *Appendix A.* Categories covered by these facts include physics, cognitive psychology, genetics, and other science disciplines. Audio stimuli were created using the Microsoft Windows Text-to-Speech program on a laptop running a Windows 8.1 operating system and were recorded using Audacity software (Audacity Team, 2012. Audactiy® Version 2.0.0). The automated voice used to play the trivia facts that were recorded was Microsoft David Desktop – English (United States) reading each fact at normal speed. Participants heard the trivia facts through a pair of over-ear headphones; they were not provided with written versions of the trivia.

The cues used in the test phase were derived from the grammatical subjects of the facts presented during the study phase. All cues started with the phrase “What is the statement about" and included the cues provided in *Appendix A.* Test materials were the same for all participants.

Procedure

All stimulus presentation and testing was done individually on a computer. Participants were seated in a cubicle that contained a single table and chair. The door to the cubicle was closed during the experiment. Participants were allowed to adjust the location of the monitor and keyboard and the height of the chair so that they were comfortable. Participants were assigned to one of two conditions upon arrival. All participants were instructed that during the study phase they would listen to trivia facts, one at a time, each fact played only once, and that after hearing a fact they should use the computer keyboard to type notes that they thought would help them remember the fact. After participants typed a note and hit the enter key, they were prompted with a message on the screen to select a folder in which to save the notes they just typed. The available folder choices were 1. Red, 2. Orange, 3. Yellow, 4. Green, 5. Blue, 6. Purple. Participants indicated their choice by pressing the number on the keyboard that corresponded to the folder of their choice. Upon pressing a number, participants were shown a screen indicating the folder they had chosen. Participants were instructed to spread the facts evenly among the folders so they could not save all of the facts into the same folder and then have easy access to their notes during the test. To make this task easier, participants were provided with a count of how many facts were already in each folder after each choice. Actual prompts that were given to participants during the task are provided in *Appendix B.*

During initial instructions, participants were informed that some participants would be allowed to access folders during the test phase of the experiment while others would not.

For half of the participants, the instructions further indicated that they were in the Access group and that during the test phase they would be allowed to view a folder into which they had saved notes, provided that they correctly recalled where they stored the notes for the fact they were being asked to recall. They were informed that during the test they would be asked if they wanted to access a folder to use their notes for a particular fact and if they correctly typed the name of the folder where the relevant fact was stored they would see the note for that fact. For the remaining participants, the instructions further indicated that they were in the No Access group and they would not have access to any folders during the test phase.

Upon completion of the study phase, participants were given a short (five-minute) distractor task in which they were tasked with pressing one of two keys to indicate which letter appeared on different sides of the screen. The purpose of the task was to create a delay between the study and test phases. After the task, participants were provided with cued recall test instructions, which were the same across all participants. At this time, they were also informed that no participants would actually have access to their notes during the test. The test instructions were to type in the fact associated with the cue presented on the screen. They were prompted with the phrase "What is the statement that you heard about *recall cue*?" Upon pressing enter to submit a response, participants were asked to recall in which folder the note about the fact associated with the cue was saved during the study phase. They were not given choices but were allowed to type in any response. Generally, participants typed the names of the folders, although two participants typed in the numbers that they pressed in order to choose a folder during the study phase.

Scoring

Each cued recall response for the facts was scored in a binary fashion as correct or incorrect based on the idea units in the response. Idea units constituted the noun phrases, adjectives, and verbs that contributed to the meaning of the statement (e.g., Dunlosky, Hartwig, Rawson, & Lipko, 2011; Hartley & Cameron, 1967). Redundant terms as well as terms contributing only to the grammatical structure of the statement were excluded. Synonymous terms and misspellings were accepted. The idea units for each fact are shown in *Appendix A.*

Only responses containing all of the relevant idea-units (or variations of those units) were marked as correct. The response did not have to repeat the information included in the cue. Responses that were missing any idea units were marked as incorrect. That is, incorrect responses did not include all idea units needed to make the fact true. Many of the easier facts did not require detailed responses to be correct. For instance, “owls = parliament” was considered correct for the fact “The collective term for a group of owls is a parliament” because the meaning of the fact was conveyed. If the participant response was “owls are groups,” it was considered incorrect because not all of the relevant information was included. Folders were marked as correct when the color or number of the folder where the note on a fact was stored was correctly typed. Misspellings were accepted. Two raters independently scored participant responses; after scoring five participants, the raters were at 96% agreement. Upon reviewing the cases in which the raters did not agree, clarifications were made about what information was important for each fact and agreement increased to 99%.

Results and Discussion

Preliminary results for this experiment were originally presented in Slavina (2015). The data were subsequently re-analyzed and are reported here.

Cued recall

Proportion correct cued recall was examined with a 2 (Access Group) x 2 (Difficulty) x 2 (Test Content) ANOVA. The means are shown in *Figure 2*. Main effects and interactions are shown in

Table 1. There was a main effect of fact difficulty. Overall recall was higher on trials with easy facts (*M* = .60, *SE* = .04) than on trials with hard facts (*M* = .20, *SE* = .03). There was a main effect of test content. Recall was higher for folders (*M* = .50, *SE* = .03) than facts (*M* = .40, *SE* = .03), not unexpected given that there were only 6 possible folders and 36 possible facts.

Importantly, the main effects were qualified by an interaction between difficulty and test content. When facts were easy, fact recall (*M* = 0.59, *SE* = 0.04) and folder recall (*M* = 0.57, *SE* = 0.04) were comparable. When the facts were hard, fact recall (*M* = 0.20, *SE* = 0.03) was lower than folder recall (*M* = 0.42, *SE* = 0.03). There was no main effect of access group nor were there any other significant interactions.

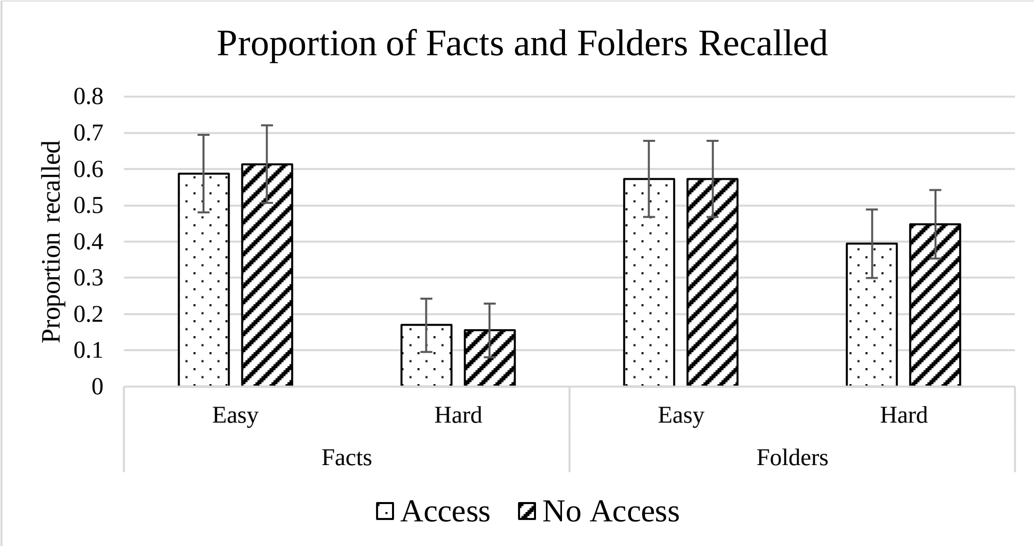

Figure 2. *Proportion of easy and hard facts and folders recalled for each access group. Error bars are 95% confidence intervals.*

Table 1. 2 (Access Group) x 2 (Difficulty) x 2 (Recall Content) repeated measures ANOVA.

Source	SS	df	*MSE*	*F*(1,36)	*p*	Partial η^2
Access	.01	1	.01	.114	.738	.00
Difficulty	3.31	1	3.31	156.12	< .0001	.81
Content	.51	1	.51	10.89	.002	.23
Access x Content	.00	1	.00	.09	.77	.00
Access x Difficulty	.00	1	.00	.02	.90	.00
Difficulty x Content	.78	1	.78	49.99	< .0001	.58
Access x Difficulty x Content	.02	1	.02	1.33	.26	.04
Error	.56	36	.02			

There was no evidence at all that expecting access to stored information had any impact on memory. This was unexpected and will be discussed in the context of participant strategies below. There was an effect of difficulty on overall recall, and recall was better for facts than folders. Neither of these main effects is surprising. Although an interaction was predicted, it was somewhat different than expected. As expected, participants recalled more easy facts than hard facts and, as predicted, when the facts were hard, recall of the folders was higher than recall of the facts. Somewhat unexpected was that when the facts were easy, participants recalled facts and folders at a similar rate. It was predicted that when the facts were easy, participants would not feel the need to also encode the folders where they stored their notes because they would feel confident in their ability to remember the facts. The data show that this was not the case, as participants showed similar recall for easy facts and folders. Something else contributed to participant memory for folders when facts were easy. It may be that the act of deciding where to store information is important to folder memory.

Strategies

At the end of the experiment, participants described the strategies that they employed for determining the folder in which each note was stored. On the basis of the open-ended responses, strategies were split into two categories: strategies that related the facts to the folders and strategies that were unrelated to the facts, such as random or sequential assignment. Participants were considered to have used a strategy if they reported somehow making associations between the contents of the facts and the names of the folders in which their notes were saved. Participants in both access groups appeared to use similar strategies. In both access groups, around 79% of participants responded that they used a strategy that related the subject of the fact to the color or number of the folder to which the fact was assigned. The request to evenly distribute the notes did not seem to interfere with participants' ability to formulate and follow a strategy. It seems that regardless of whether or not participants were told that they would be able to access their notes, the participants put effort into assigning facts to folders. The instructions to choose where to store the notes directed all participants to think about the names of the folders and to connect them to the contents of the facts on which they took notes. As a result, participants in both access groups recalled similar levels of folders. Also as a result, recall of folders was high even when the facts were easy.

Note quality

It was predicted that participants in the no access group would focus less on the folders than participants in the access group, but there was no indication in the memory results that participants in the no access group approached the encoding task differently than the access group. Rather, the recall results suggested that all participants were trying to do the task as if they would have access to the notes. It is possible, however, that differences between the groups could be found in the quality of the notes. Participants expecting access might have had higher quality notes than those not expecting access.

Note quality was determined by how useful the notes may have been if they were available during the recall test. Usefulness was determined by the presence of idea units in each note. Notes that were unrelated to the fact, had missing information, or were misrepresentations of the fact were rated as poor notes. Notes from which the facts could be reproduced either in full or with the same meaning as the original were rated as good notes. Because hard facts contained, on average, more idea units, notes were more likely to be scored as good for easy facts. Two raters categorized all participants' notes as either good or poor. The agreement between the raters, measured as Cohen's kappa, was .97, $p < .0005$.

An exploratory analysis of proportion of good notes was done with a 2 (Access Group) x 2 (Fact Difficulty) ANOVA. Means are shown in *Figure 3*. Just as with the recall data, there was no main effect of access and no interaction involving access. Main effects and interactions are shown in *Table 2*. There was a main effect of difficulty. The proportion of good notes for easy facts ($M = .72$, $SE = .04$) was greater than the proportion of good notes for hard facts (*M* = .32, *SE* = .04). The hard facts, which contained topic-specific vocabulary that might not have been familiar to the participants, appeared to be more difficult for participants to understand and to capture in the note-taking process. This was reflected in the lower proportions of good notes for hard facts.

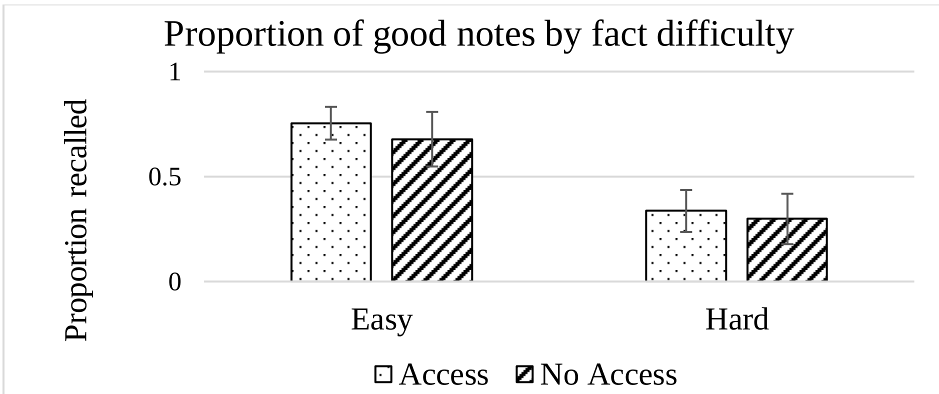

Figure 3. *Proportion of good notes for easy and hard facts by participants in the access and no access groups. Error bars represent 95% confidence intervals.*

Table 2. 2 (Access Group) x 2 (Difficulty) repeated measures ANOVA for note quality (proportion of good notes).

Source	SS	df	*MSE*	*F*(1,36)	*p*	Partial η^2
Access Group	.06	1	.06	.66	.42	.02
Difficulty	3.03	1	3.03	121.47	< . 0001	.77
Access Group x Difficulty	.01	1	.01	.28	.60	.01
Error	.90	36	.03			

Participants did not show the pattern of behavior that was expected based on the conclusions drawn by Sparrow et al. (2011). Participants who believed that their notes were saved on a computer and that they would be able to access them during the test if they remembered where they were saved did not behave differently from participants who believed their notes would be inaccessible during the test. Participants who were led to believe that they would not benefit from remembering the names of the folders where they stored their notes wrote similar quality notes and recalled comparable proportions of folders.

The hypothesis that participants in the access group would recall more folders than participants in the no access group was not supported. Participants in the no access group were expected to rely more on their internal memory, which would have led to a higher proportion of facts correctly recalled, because they would not have been able to use their notes during the test. The hypothesis that participants in the no access group would recall more facts also was not supported. When the facts were easy, participants were expected to recall more facts and not to rely on being able to remember where they put their notes because that information would not have been helpful. This was not the case, as participants in both groups recalled comparable proportions of easy facts and folders.

The only case in which participants recalled more folders than facts was when the facts were difficult. But, the exploratory analysis of note quality showed low quality notes for hard facts. When participants took poor notes, they were still able to successfully connect the subject of the fact to the name or number of a folder. As evidenced by the high proportion of participants in both access groups who employed strategies for choosing folders, it could be that participants recalled the names of folders *because* the instructions required them to put some effort into processing them. Experiment 2 was designed to examine whether the act of choosing folders was actually driving participant memory for folders.

Experiment 2

In Experiment 2 all participants were led to believe they would be able to access their notes if they remembered where they stored them. This procedure is more closely aligned with Sparrow et al. (2011, Experiment 3) in which participants were told that some of the facts they were typing into a computer would be saved on the computer and that they would be able to access those notes if they could remember where they had been saved. Each

Sparrow et al. participant had some notes that were saved into named folders, some that were saved in an unspecified location, and some that were not saved on the computer at all. This was a within-subject manipulation to determine if participants would treat information differently based on whether or not it was saved on a computer. The results of Sparrow et al. showed that they did, remembering more unsaved facts and more folder than fact information for saved facts. In contrast, the results of Experiment 1 (this paper) showed no differences in either fact memory or folder memory between participants who were told that they would not have access to their notes and those who were told that they would.

A major difference between Sparrow et al. (2011, Experiment 3) and Experiment 1 was the way in which notes were assigned to folders. In Sparrow et al. notes were randomly assigned to folders, which made participants the passive recipients of the folder information, while in Experiment 1, participants actively chose where to save each note. It is possible that having to choose where to store the notes increased the likelihood that participants would remember where their notes were stored, possibly to the detriment of memory for the facts. To examine this possibility, half of participants in Experiment 2 had to choose where to put their notes and the other half had their notes "randomly" assigned to folders. All participants were all told that they would be able to access their notes during the test if they remembered where they stored their notes, so they should be similarly motivated to encode the folder information, at least for hard facts that participants thought they might not remember. If the act of choosing where to store each note was what lead to comparable recall rates for participants in the access and no access groups in Experiment 1, participants who choose where to put their notes should recall more folders than participants who do not.

An unexpected finding of Experiment 1 was that folder recall was high for easy facts. It had been predicted that all participants would recall the facts that they found easy to encode and that they would not necessarily recall the folders associated with those facts because that information would not have been considered helpful. To test whether participants actually make judgments at encoding about fact difficulty and the need to remember folders, participants in the current experiment who made folder choices were told that out of the 36 facts on which they would take notes, only 24 of those notes could actually be saved. If participants found the easy facts easy to remember, then they would presumably not feel the need to save the notes for those facts. That is, it was hypothesized that participants making folder choices would choose to save fewer notes for easier facts.

According to dual-process theories of higher cognition, people are reluctant to engage in activities that require using cognitive resources when easier options may be available. This idea, that humans are cognitive misers (e.g., Kahneman, 2011; Stanovich, 2009), is based on the theoretical assumption of two types of mental processes: Type 1 and Type 2. Type 1 processing occurs rapidly and involves less cognitive effort than Type 2 processing. Type 1 processing is basically retrieving information from memory. An example of Type 1 processing is the ease with the answer springs to mind in response to the question "What is 2+2?" Type 2 processing, on the other hand, makes larger demands on cognitive resources, as when one is engaged in hypothetical thinking (e.g., Evans & Stanvich, 2011). An example of Type 2 processing is the difficulty in answering the question "What is 1345/5 + 131/100?" The soft constraints hypothesis (Gray, Sims, Fu, & Schoelles, 2006) is that people choose to engage in cognitive (or motor) processes that require the least amount of effort while achieving the desired result. In the case of the current research, participants may choose to encode facts in memory when it is easy to do so and may choose to encode the folders where they can access those facts when the facts are hard and encoding the folders seems relatively easier. Because the act of choosing a folder might make it easier to encode the folder, it was hypothesized that participants who chose folders would encode more folders than facts in situations where the facts are hard. For participants who did not get to choose where to save their notes, the act of encoding a folder may not be easier than encoding a fact, so these participants may actually end up encoding more facts than folders. For this reason, it is also hypothesized that participants who choose where to save their notes will selectively recall more folders than participants who do not choose. That is, it was hypothesized that participants who did not choose where to save their notes (those in the no-choice condition) would remember more facts than those who chose, and participants who chose where to save their notes (those in the choice condition) would remember more folders than those who did not.

Method

Participants and design

There were 80 undergraduate participants (31 males and 49 females) from Iowa State University who completed the study for course credit. The average age was 19.5 years (SD = 1.6). Participants were assigned to groups with 40 assigned to the Folder Choice group and 40 assigned to the No Folder Choice group. Group assignment served as a between-subjects variable while fact difficulty and content recalled (fact or folder) served as within-subjects variables.

Stimuli and materials

Stimuli included all of the statements used in Experiment 1. Audio stimuli were created using the Apple text-to-speech program on a MacBook Air running macOS 10.10.2. The voice used was Allison and the play speed was slower than normal but not the slowest available setting. This speed adjustment was done because participant notes from Experiment 1 indicated that some facts were misheard or found to be difficult to parse. Each statement was recorded using Audacity software (Audacity Team, 2012. Audacity® Version 2.0.0). Participants heard the statements through a pair of over-ear headphones; they were not provided with written versions of the statements.

The cues used in the study and test phase were the same as those used in Experiment 1 and can be found in *Appendix A.* The same cues were used during the study phase and the test phase.

Procedure

The instructions provided to participants before the study phase were slightly different for the participants in the folder choice group and the no folder choice group.

<u>Folder Choice Group</u>

Participants in the Folder Choice group were informed that they would be listening to 36 statements and that they would have the opportunity to take notes on each statement after they heard it. They could then choose where to save the notes. Only 24 notes could be saved in one of the six folders named after colors of the rainbow: RED, ORANGE, YELLOW, GREEN, BLUE, PURPLE. The remaining 12 notes were not saved. They were told that on each trial, they would be provided the number of notes they could save alongside the number of notes already saved in each folder. They were additionally informed that they would be tested on the statements, and if they could correctly recall the folder where they stored notes on a particular statement, they would be able to access those notes during the test.

Participants were then provided with an example of a statement that they were given the opportunity to take notes on. They were then given the option of saving the statement in one of six folders (for this example they were not given the option of not saving the notes). Then they were shown what the test phase would look like if they could correctly recall where their notes were stored. Another example was given of what would happen if they chose not to save their notes. While there was no actual limitation to how many notes could be saved in each folder, participants were informed that they would only be able to access the notes within a particular folder if there were no more than four notes saved in that folder. This was intended to encourage participants to distribute their notes evenly amongst the folders.

No Folder Choice Group

Participants in the No Folder Choice group were informed that they would be listening to 36 statements and that they would have the opportunity to take notes on each statement after they heard it. They would then be informed of whether or not their notes were saved and in which folder they were saved. Each participant in the no choice group was yoked to a participant in the choice group, so that the facts that were not saved for a participant in the choice group were also not saved for a participant in the no choice group. This was done because participants in the choice group chose to save more notes for hard facts than for easy facts, and randomly assigning which notes were not saved would make it difficult to compare recall for saved and not saved facts across the two groups. The names of the folders were the same as for the choice group. Data were collected from all participants in the choice group before data collection began for the no choice group. Because participants in the choice group were expected to choose to not save their notes for facts that were easy and because between-group comparisons were planned, after data were collected from participants in the choice group, a new study file was created to be used with the yoked no choice participant such that the same facts were not saved for both. All saved facts for the no choice participants were randomly but equally assigned to folders.

Study phase

During the study phase, participants listened to each of the 36 statements presented in random order. After hearing a statement, the participant was provided with a cue for the

In which folder would you like to save the notes you just typed?
The number next to the color indicates the number of notes already stored in that folder.
1 = RED (1)
2 = ORANGE (2)
3 = YELLOW (1)
4 = GREEN (3)
5 = BLUE (1)
6 = PURPLE (0)
7 = NOT SAVED (0)
TOTAL SAVES REMAINING: 16

Figure 4. Prompt for participants in the choice condition to choose where to save their notes. Note that one of the options is to not save notes. Participants were provided with a counter of how many of their remaining notes they could save.

statement and instructed to take notes on the statement about that cue (e.g. “Type your notes for the fact about *the king of hearts*”). Participants in the folder choice group were then shown a list of possible folder choices as well as how many notes were stored in each folder and how many more notes they could save. From this list they could select to save their notes in any of the six folders or to not save their notes. Once they ran out of notes that could be saved, all subsequent notes were not saved. The prompt for participants to choose where to save their notes is shown in *Figure 4*.

Participants in the no folder choice group, after typing in notes, were shown where these notes were saved or were informed that the notes were not saved. Participants in this group were shown a similar prompt to the one shown in *Figure 4* but without the option of choosing a folder so that participants in each group had equal amounts of exposure to the names of the folders.

Test phase

Upon completion of the study phase, all participants were given a distractor task, which entailed identifying where a letter appeared on a screen (the same distractor task was completed by participants in Experiment 1). The distractor task took five minutes to complete and served to deter rehearsal of the statements heard during the study phase as well as to put some time between study and test. After the distractor task, all participants were informed that nobody would have access to their notes during the test. They were then asked to type in the statement associated with the cue that was presented. After they typed in the statement associated with the presented cue, they were asked where the notes related to the statement about the same cue were saved. They were not given any choices and were simply provided with a text-entry box in which they were able to type whatever they wanted. All participants typed the names of the folders rather than the numbers they had to press in order to select between folders during the study phase. The cues that were presented were the same as those used during the study phase.

Results and Discussion

Forty matched pairs were run, but four participants were removed from the choice condition because they failed to provide responses for most or all of the folder recall questions. One removed participant provided fewer than 10 responses and the remaining three provided no responses. Their yoked no-choice participants were also removed, leaving 36 matched pairs. Only matched pairs were analyzed to insure that difficulty and which items were saved and not saved were the same in each choice condition. Proportion of items recalled was examined with a 2 (Choice Group) x 2 (Difficulty) x 2 (Recall Content) ANOVA. The means are shown in *Figure 5*. Main effects and interactions can be seen in *Table 3*.

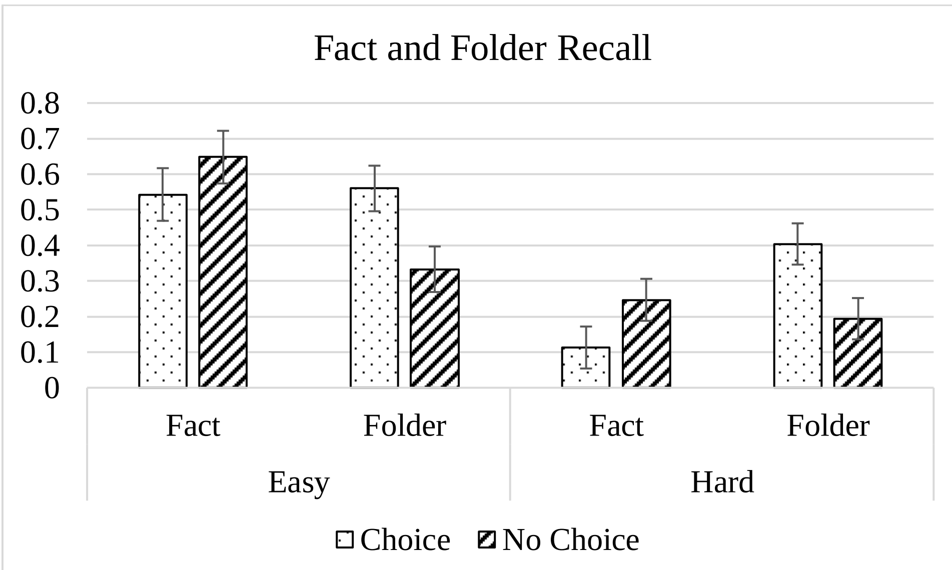

Figure 5. *Proportion of easy and hard facts and folders recalled in the choice and no choice groups. Error bars represent 95% confidence intervals.*

Table 3. 2 (Choice Group) x 2 (Difficulty) x 2 (Test Content) Repeated Measures ANOVA.

Source	SS	df	*MSE*	$F(1,70)$	p	Partial η^2
Group	.18	1	.18	2.15	.15	.03
Difficulty	5.71	1	5.71	313.16	< .0001	.82
Group x Difficulty	.01	1	.01	.53	.47	.01
Content	.02	1	.02	.42	.52	.01
Group x Content	2.06	1	2.06	55.72	< .0001	.44
Difficulty x Content	1.30	1	1.30	97.35	< .0001	.58
Group x Saved x Content	0.00	1	0.00	.05	.82	.00
Error	.93	70	.01			

There was a main effect of difficulty, with higher performance on trials associated with easy facts (*M* = .52, *SE* = .02) than hard facts (*M* = .24, *SE* = .02). This effect was also found in Experiment 1 and confirms that there was a difference in terms of how difficult the easy and hard facts were to recall. Also as in Experiment 1, there was an interaction between recall content and difficulty, which is shown in *Figure 6*. When facts were hard more folders were recalled (*M* = .30, *SE* = .02) than facts (*M* = .18, *SE* = .02) and the reverse was true when facts were easy (folders *M* = .45, *SE* = .02; facts *M* = .60, *SE* = .03). In Experiment 2, however, there also was a reliable difference between the two groups in terms of which content was recalled.

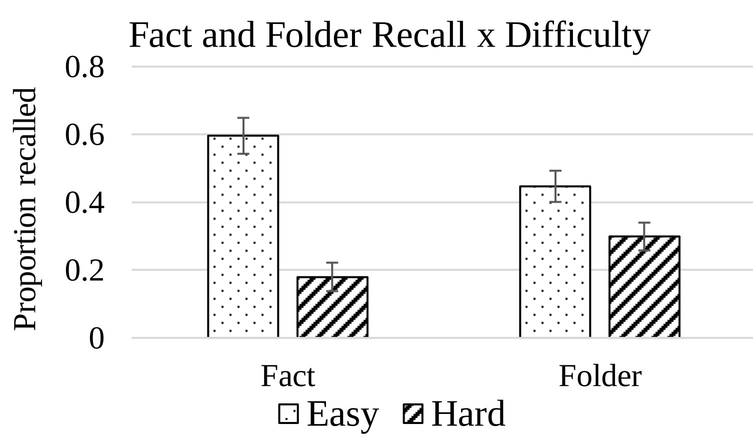

Figure 6. Proportion of easy and hard facts recalled collapsed across choice group. Error bars represent 95% confidence intervals.

The interaction between group and recall content is shown in *Figure 7*. Participants in the choice group recalled fewer facts and more folders (folders *M* = .48, *SE* = .03; facts *M* = .33, *SE* = .03) while participants in the no choice group recalled more facts and fewer folders (folders *M* = .26, *SE* = .03; facts *M* = .45, *SE* = .03). This interaction fits with the hypothesis that participants who got to choose where to save their notes would expend more effort in remembering where they put their notes and less effort in remembering the facts than participants who did not get to choose. The lower rate of recall for facts and higher recall for folders among participants in the choice condition seems to indicate that a tradeoff was made between remembering more folders and remembering fewer facts.

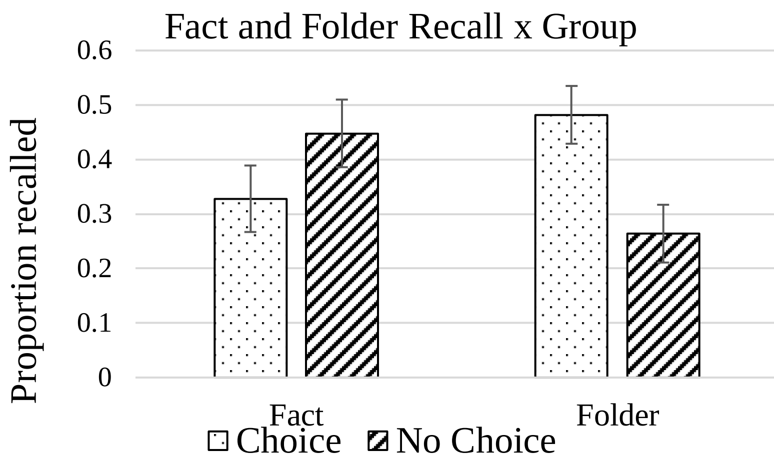

Figure 7. Proportion of facts and folders, collapsed across difficulty, recalled in the choice and no choice groups. Error bars represent 95% confidence intervals.

Note saving

The previous analysis confirmed some of the findings of Experiment 1 and indicated that participants in the no choice group performed better on fact recall while participants in the choice group performed better on folder recall. Aside from whether or not participants got to choose where facts were saved, Experiment 2 was different from Experiment 1 in that not all notes could be saved. Which notes were saved was determined by participants in the choice condition who were informed that they would only be allowed to save 24 out of the 36 facts that they would hear and be tested on. Based on the assumption that they would be more confident that they would be able to remember the easy facts and, thus would not need access to the notes, it was predicted that fewer notes would be saved for easy facts than hard facts. That prediction was confirmed. Participants in the choice condition saved more notes for hard facts (M = 13.5, SE = 0.34) than for easy facts (M = 10.5, SE = 0.34), $t(35) = 4.53$, $p <$ .0001. The effect size was quite large (Cohen, 1988), Cohen's d = 1.51.

If participants in the choice condition were offloading memory for facts in favor of remembering where they could access their notes for the facts, their recall for saved folders should be higher than that of no-choice participants and their recall for unsaved facts should be higher. Following the same logic, fact memory should be lower for participants in the choice condition than the no choice condition for saved facts, but at least as high or higher for unsaved facts. These hypotheses were examined via direct comparisons between the groups. The fact and folder recall as a function of saved status are shown in *Figure 8* for each group.

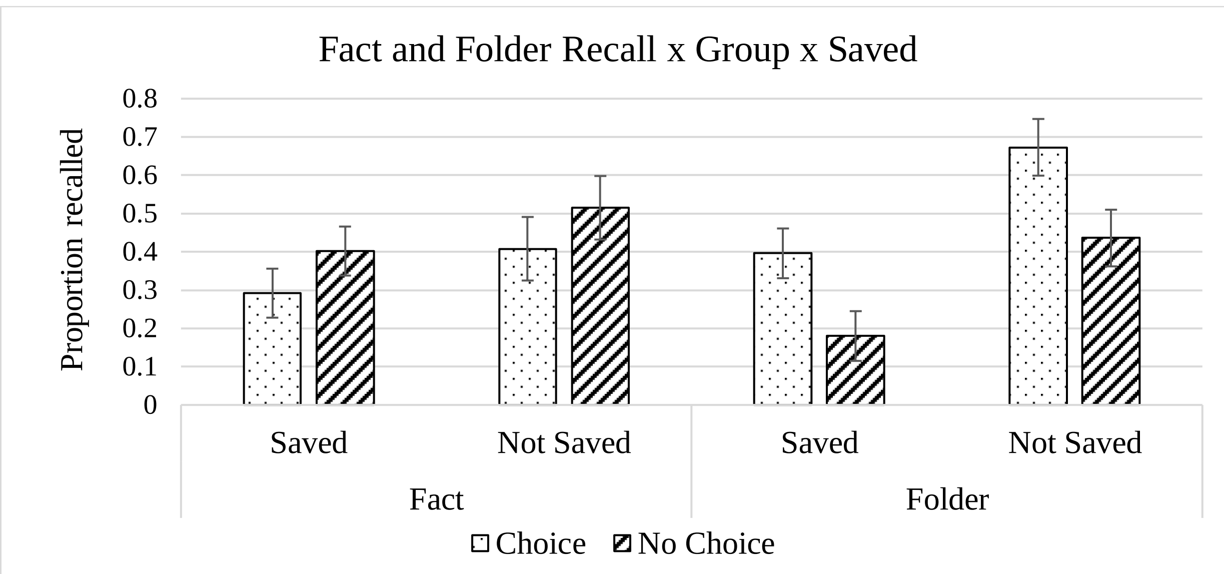

Figure 8. Proportion of facts and folders recalled when notes saved or not saved. Error bars represent 95% confidence intervals.

Participants in the choice group had higher recall for folders where notes were saved (M = .40, SE = .04) than did participants in the no choice group (M = .18, SE = .02), $t(35)$ = 4.73, $p < .0001$. The effect size was quite large (Cohen, 1988), Cohen's d = 1.14. The low rate at which participants in the no choice group recalled folders when notes were saved indicated that they were performing close to chance level (they had a 16.67% chance of correctly guessing one of the folders), so it is likely that they were not paying attention to the specific folders where their notes were saved. Participants in the choice group also more frequently recalled which notes for facts were not saved (*M* = .68, *SE* = .04) than participants in the no choice group (*M* = .44, *SE* = .03). That is, participants in the choice group had better memory for which facts they did not save as well as for the folders where they had saved facts. In this case, participants in the no choice group were performing somewhat better than chance (if they were to guess which notes were not saved they would have a 33.33% chance of guessing correctly), which implies that even if they were not attending to specific folders where their notes were saved, they were at least partly encoding whether or not a note was saved.

As predicted, participants in the choice group recalled fewer facts that were saved (*M* = .29, *SE* = .03) than participants in the no choice group (*M* = .40, *SE* = .04), $t(35) = 2.6$, $p = .01$, and the effect size was medium (Cohen, 1988), Cohen's $d = .57$. Somewhat unexpected is that participants in the choice group also recalled fewer facts that were not saved (*M* = .41, *SE* = .03) than participants in the no choice group (*M* = .52, *SE* = .04), $t(35) = 2.3$, $p = .03$, and the effect size was medium (Cohen, 1988), Cohen's $d = .44$. It could be that participants in the choice group were overly confident about their ability to remember the facts that they chose not to save. It could also be that there was just more focus on the facts themselves in the no choice group. This possibility aligns with findings regarding note quality that are reported next.

Note Quality

In Experiment 1, when notes were analyzed on a binary scale that distinguished between good and poor notes, it was noted that some participants may have experienced difficulty in being able to clearly hear the facts, which made reliably rating note quality difficult. This difficulty was addressed in Experiment 2 by re-recording the facts using a clearer and slower voice. In Experiment 2, notes were analyzed by two independent raters for the proportion of idea units that were present. High agreement was found between the two raters, Cohen's $\kappa = .83$, $p < .0005$.

Note quality was of particular interest, because only participants in the choice group were able to choose which of their notes they could save for later use during the test. Note quality was examined with a 2 (Choice Group) x 2 (Fact Difficulty) x 2 (Saved or Not) ANOVA. The means are shown in *Figure 9.* Main effects and interactions are shown in

Table 4.

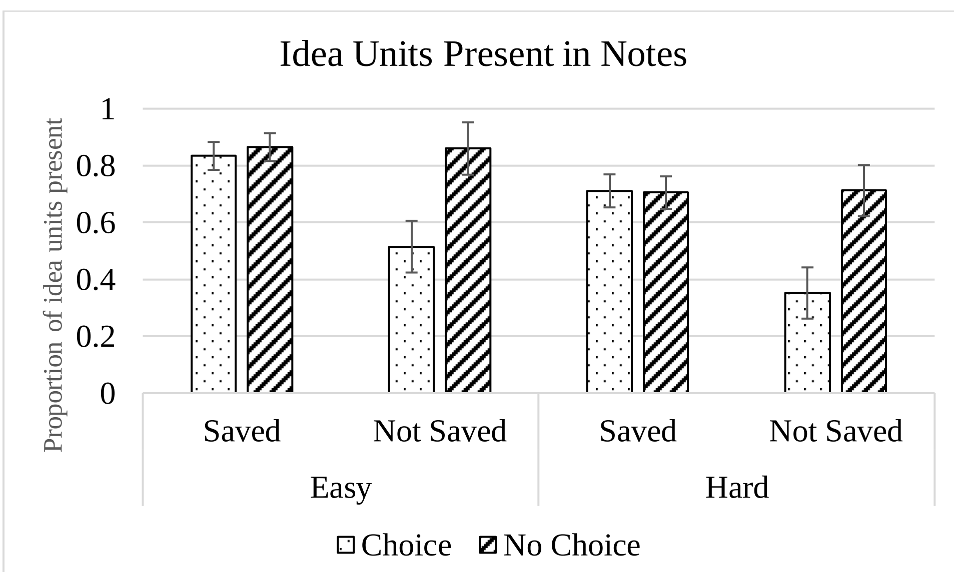

Figure 9. Average proportion of idea units present in participants' notes. Error bars represent 95% confidence intervals.

Table 4. 2 (Choice Group) x 2 (Fact Difficulty) x 2 (Saved or Not) repeated measures ANOVA for Note Quality.

Source	SS	df	*MSE*	*F*(1,70)	*p*	Partial η^2
Group	2.40	1	2.40	20.42	< .0001	.23
Difficulty	1.59	1	1.59	120.00	< .0001	.63
Saved	2.06	1	2.06	37.53	< .0001	.35
Group x Difficulty	.00	1	.00	.15	.70	.00
Group x Saved	2.07	1	2.07	37.79	< .0001	.35
Difficulty x Saved	.00	1	.00	.19	.66	.00
Group x Difficulty x Saved	.01	1	.01	.76	.39	.01
Error	1.13	70	.02			

As in Experiment 1, there was a main effect of difficulty. Notes were of higher quality for easy facts (*M* = .77, *SE* = .02) than for hard facts (*M* = .62, *SE* = .02). There was a main effect of group in which participants in the choice group had lower quality notes overall (*M* = .60, *SE* = .03) than participants in the no choice group (*M* = .79, *SE* = .03). There also was a main effect of whether or not the notes were saved. Notes that were saved were of higher quality (*M* = .78, *SE* = .02) than notes that were not saved (*M* = .61, *SE* = .03). The latter two effects were qualified by an interaction between whether or not the notes were saved and choice group. Participants in the choice group had better notes when the notes were saved (*M* = .77, *SE* = .02) than when they were unsaved (*M* = .43, *SE* = .04), but participants in the no choice group had notes of comparable quality when the notes were saved (*M* = .79, *SE* = .02) and when they were unsaved (*M* = .79, *SE* = .04).

Participants in the no choice group, who did not know in advance which notes were going to be saved, did not have the opportunity to modify their note-taking behavior according to whether or not they might be able to use any given note, so all notes were of relatively high quality. Participants in the choice group did have that opportunity and ended up having lower quality unsaved notes than saved notes. The overall higher quality of the unsaved notes for the no choice group in comparison to the choice group was associated with a higher level of recall for unsaved facts. This finding aligns with the encoding theory of note-taking, in that high quality notes should enhance overall encoding of the facts, which supports better later recall.

The relationship between note quality and recall was also examined via correlations. There was a positive correlation between note quality and fact recall both for hard facts (r = .45) and for easy facts (r = .53). Among participants in both groups, higher note quality was associated with better fact recall. Because participants took notes after they heard a statement, rather than during, note-taking could be viewed as a form of retrieval practice. Better note-taking, or better retrieval practice, should lead to better recall.

The positive correlation between note quality and fact recall, along with the difference in quality of unsaved notes, may account for why participants in the no choice group recalled more facts overall than participants in the choice group. The correlations between note quality and fact recall were somewhat weaker for participants in the no choice group (hard facts r = .49, easy facts r = .55) than the choice group (hard facts r = .55, easy facts r = .64), which makes sense because there was less variability in their note quality, as evidenced by the comparable quality between unsaved and saved notes. Not only did participants in the choice condition miss an opportunity to practice recalling the facts that they did not save, as can be inferred from their lower quality unsaved notes, but they also seemed to have been relying more on being able to access their notes by recalling the folders where they were stored.

General Discussion

During Experiment 1 all participants completed the same task, but half of them were led to believe that they would be able to access the notes that they typed during the study phase while they were taking a recall test. The other half of participants were led to believe they would not be able to use their notes. Regardless of whether or not participants were told they would have access to their notes, they behaved similarly on all variables. Participants in both access groups described using strategies to try to connect facts and folders even though doing so would only benefit those participants who were told they would be able to use their notes. No differences were found between the two groups in recall for facts or folders.

It appears either that all participants actually believed that they would have access or that the requirement to assigning notes to folders, which would have directed attention to the folders in both groups, encouraged both groups to approach the task in a similar fashion. The act of choosing the folders in which to save their notes likely directed participants' attention to the folders and most participants, because they already had to think about the folders when making the decision, took a strategic approach to the task. Ostensibly most of the participants, regardless of what they were lead to believe about the accessibility of their notes, devoted at least some of their limited working memory capacity to the act of relating facts to folders.

Overall, participants in Experiment 1 recalled comparable proportions of facts and folders when the facts were easy but more folders than facts when the facts were hard. This result could indicate that participants had enough mental resources to encode the facts together with the folders when the facts were easy, but that they had to make a tradeoff between fact and folder recall when the facts were hard. In order to further investigate whether such a tradeoff was occurring, possibly as a result of choosing in which folders their notes would be saved, Experiment 2 compared recall for facts and folders between participants who got to choose where to save their notes and participants who did not.

The results of Experiment 2 showed differences in recall and note quality between those who did and did not choose the folders, and the pattern of differences suggested that participants who chose where to save their notes were making a tradeoff between fact memory and folder memory. Choice participants altered the quality of their notes based on whether or not the notes were going to be saved. Saved notes, which participants presumed would be available during the test, were of higher quality than unsaved notes. In addition, in comparison to the no-choice group, memory for the saved facts was lower but memory for the folders was higher. Together, the change in note quality and memory for where rather than what indicate a willingness to rely on the notes at the time of test at the expense of memory for the facts.

This result shows the pattern described by Sparrow et al. (2011), indicating a reliance on external memory over internal memory. Participants who chose where to save their notes, much like all of the participants in Experiment 1, were tasked with thinking about where to save each note by being asked to evenly distribute their notes. Perhaps because they were already thinking about the folders, they took that as an opportunity to offload encoding facts to encoding where they can find their notes about the facts. Oberaurer et al. (2016) noted that new information entering working memory may interfere with already encoded information. In the case of participants in the choice group, because the choice of where to save the notes occurred after creating the notes, participants may have focused more on the note-location information than on the facts themselves. That is, when the new information about where they put the note entered working memory, it may have interfered with the information about the fact, so that is was less effortful to remember the fact-folder information than to remember the fact. By taking the notes and remembering where they were saved, the mental burden of keeping each fact in mind was removed so that new facts could be considered without the interference of old facts.

Participants in the no choice group did not determine which notes would be saved, and thus available during the test phase; they were simply informed. Because they were not forced to choose in which folder to store each note, their attention was not drawn to the folders or to making connections between the facts and folders, and they were less likely than choice participants or participants in Experiment 1 to form a fact-folder association. In fact, if they wanted to remember which fact went into which folder, they would have been faced with a much harder task, because they did not know in advance where each note was going to be saved and would have had to have made a retroactive connection between facts and folders. Because of the random nature of folder assignment for these participants, the likelihood that a new folder would interfere with memory for previous folders was higher for them than for the participants in the choice group because they could not associate a folder with a category to simplify the associations made between facts and folders. It appears that instead of devoting extra effort to trying to remember which notes went into which randomly assigned folders, participants in the no choice group focused their efforts on trying to remember the facts, as indicated by their recalling facts better than participants in the choice group. Without knowing which notes would be saved, participants in the no choice group also ended up with notes of comparably high quality for all facts. Creating high quality notes for each fact from memory after listening to it likely helped them remember the facts by acting as a recall practice.

Participants in the choice condition could also have benefitted from the same recall practice, but because they could begin to make the choice about where to put a note as they were creating it, they devoted less effort to note creation. The low quality of unsaved notes may indicate that they were confident in their ability to remember the unsaved facts and thus did not devote as much effort to remembering them. This could be an example of the fluency effect (see Alter & Oppenheimer, 2009 for a review of the fluency effect), wherein the easy facts, which were disproportionately represented among the unsaved notes, were considered too easy to expend effort on really trying to encode them. The generally high rate of recall for easy facts indicates that they were easy enough to remember without having to rely on notes. Alternatively, some of the mental effort that could have been devoted to encoding each fact could instead have been devoted to deciding whether or not the note for that fact would be saved, and for the notes that would be saved, in which folder that note should go. In trying to figure out where to save their notes, participants would have had to recall the strategy that they had been using to associate folders with facts. Early on, when they were just figuring out the strategy, this would have been an effortful task and may have detracted from memory for facts. As they refined their strategy, it may have become easier to determine where to put each fact, but it is likely that some mental effort was still required to make the decision of whether to save the note and where to put it.

If participants in the choice group were willing to rely on their notes because they were able to strategize about where to put them, that would indicate a willingness to offload memory for information in favor of knowing where that information could be found when later needed. That is the phenomenon described by Sparrow et al. (2011) albeit in a slightly different context. Participants could have been willing to offload their memory for facts in favor of memory for folders only because they were already tasked with devoting some mental effort to choosing the folders. In the case where they were not allowed to choose, participants did not offload their memory for facts in favor of folders, which contradicts the findings of Sparrow et al., who also assigned folders randomly thereby requiring participants to really focus on remembering the folders if they wanted to offload the facts onto the computer where they saved their notes. In general, the offloading of memory for facts in favor of knowing where to find them could be problematic for learning, which requires building up a knowledge base made up of memories for facts in order to be able to understand more complex ideas and interactions (e.g., Mayer, 2002). Reliance on technology such as classroom laptops and information reference via the Internet may be influencing the way that information is approached, particularly when that technology can be relied upon to store information that would otherwise have to be remembered.

The results of Experiment 2 also support the encoding hypothesis of note-taking. Participants in the no choice group had similar quality notes for all facts, regardless of whether the notes were going to be saved or not, because they did not know which notes were going to be saved when they were taking them. These participants likely did not believe they would be able to use their notes during the test because they did not know which ones would be saved and, based on their recall for folders, did not put much effort into encoding the folders. Their better performance on fact recall likely reflected the encoding benefit of taking notes, since that is the only aspect of note-taking in which they were able to engage. Participants in the choice condition might also have benefited from the encoding aspect of note-taking, but their attention was likely split between encoding the fact and deciding on whether or where to save it.

Limitations

Although suggestive, there are limitations in real-world application of the findings to educational settings. First, the to-be-remembered information was 36 facts that were not connected to each other or related to a particular theme. Educational material is thematic and connected. Second, the names of the folders in which notes were saved were arbitrary and provided by the experimenter. They did not reflect how students might organize actual digital notes. That said, the fairly common usage of strategies for assigning facts to folders and above-chance recall for folders shows that participants were able to use the folder organization scheme without too much difficulty.

Future work

Future research should further investigate the role that note-taking plays in learning and memory by examining how students view their note-taking and whether the willingness to make a tradeoff between fact and folder memory is tied to computer-based note-taking, or if it could occur with handwritten notes as well.

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CHAPTER 3: AN UPDATED THEORY OF NOTE-TAKING

Abstract

Note-taking is a fairly ubiquitous practice in college classrooms and a large body of research has examined the relationship between note-taking and learning. Much of the research has focused on the two dominant theories of note-taking, both of which have been found to contribute to learning. The encoding theory posits that the benefits from note-taking are largely derived from the process of taking notes. The storage theory posits that the benefits of note-taking come from studying the notes that are produced. While note-taking has been previously examined from the perspective of college students (Van Meter, Yokoi, & Pressley,1994) the note-taking context has changed since that time with the widespread availability of information technologies. Through structured interviews with college students as well as a survey designed based on interview responses, the current study provides an updated perspective. While the encoding theory of note-taking still receives support from the perspective of note-takers, the storage theory did not resonate with the majority (10 out of 14) of the students who were interviewed. Additionally, the effect of online lecture slide availability on student note-taking practices is described from the perspective of students.

Chapter 2 examined the impact of computerized note-taking and digital note storage on what type of information participants remember. Participants took notes on a laptop on a series of facts and saved these notes on a computer to potentially use them during a test. The premise of the study rested on an assumption about note-taking. The assumption was that students did not just write information down that they heard without also trying to remember that information for later. The participants, all of whom were students, paid attention to the process and not just the product. The purpose of the current study was to examine that assumption and to provide a context for the experiments of Chapter 2. In order to understand the broader context of how the note-taking process might impact learning and memory, a qualitative study was conducted in which students were interviewed about their note-taking habits. The study was followed by a survey of a larger sample of students asking about themes that arose in the interview study. Of particular interest were student approaches to the process of note-taking as well as the relative importance of the product. Initially the goal of the study was to compare between handwritten note-taking and laptop-based note-taking. While participants did provide some clues about the differences between the two media, a story emerged that was not centered around these differences. It was centered around two distinct approaches that students took towards note-taking and how technology has more broadly influenced note-taking not just in terms of how notes are taken.

The following is a description of an interview-based study, in which undergraduate students were asked to talk about their note-taking habits and their purposes for taking notes, and a survey that provided a broader view of the commonality of the themes described by the interview participants. The interview and subsequent survey deal with theories of note-taking, the practice of cognitive offloading, and the interaction between note-taking and learning.

Encoding vs. Storage

The practice of note-taking, particularly in the context of academia, is ubiquitous and has been extensively studied over the past several decades (e.g., Kiewra & Benton, 1988; Mueller & Oppenheimer, 2014; Palmatier & Bennett, 1974; Van Meter, Yokoi, & Pressley, 1994). Note-taking is a worthwhile phenomenon to study because it is so common, there are so many different ways to do it, and yet it is not clear what approaches are optimal for learning. Depending on the context, the content being noted, and the intent of the person taking the notes, the act of note-taking can vary greatly between individuals. It is this wide-range of practices, purposes, and uses that make note-taking an intriguing area of study that has a rich history of research. In the early 1970s Di Vesta and Gray (1972) distinguished between two different functions of note taking that became the focus of much of the note-taking research prior to 2013: *encoding* and *storage*. Research on the *encoding* function of note-taking emphasized the mental processes involved in taking notes and how these processes can contribute to learning and memory (Jansen, Lakens, & IJsselstein, 2017; Kobayashi, 2005). Di Vesta and Gray (1972) described the *storage* function of note-taking in terms of the positive impact that studying from class notes could have on test performance. Often these two functions were pitted against each other in experiments to determine which one had a stronger impact on learning (e.g., Annis & Davis, 1975; Carter, & Van Matre 1975; Rickards & Friedman, 1978). In devising experiments to examine the encoding and storage contributions of note-taking, the two functions became part of two separate hypotheses. The encoding hypothesis states that note-taking leads to better test performance than not taking notes, regardless of whether the notes are ever studied, while the storage hypothesis states that studying from notes, regardless of who generated the notes, leads to better performance than just taking notes and not studying them. Studies that included a condition where both functions were combined (participants took notes and then studied their notes before an exam) provided evidence that the combination of encoding and storage led to stronger recall than either function alone (Bretzing, & Kulhavy, 1979; Kiewra et al., 1991; Rickards & Friedman, 1978).

The benefits of note-taking are not as straightforward as these note-taking studies might make them seem, as not all notes are created equal. Whether and how much students could benefit from taking and studying their notes seemingly depends on the quality of their notes and their note-taking speed. Peper and Mayer (1986) focused on the generative effect, which posited that the encoding benefit of note-taking derives from the cognitive processes that occur in addition to the motor processes of note-taking. They argued that by listening to (or reading) information and determining which aspects are important enough to write down and how these aspects connect to each other, the note-taker is actively processing the information and integrating it into his or her pre-existing knowledge. In order to be able to engage in deeper processing of information, however, the note-taker must be sufficiently adept at the physical skills involved in taking notes. Peverly and Sumowski (2011) examined note quality and found that participants who were more proficient at writing down notes, and could do so automatically without devoting much mental effort to the task, produced higher quality notes, which they were allowed to study before taking an exam and led to better recall for the content they had read (see also, Peverly, Garner, & Vekaria, 2014 for a similar study in which participants did not study their notes). Automaticity, however, might not be enough to produce good notes. Kiewra (1989) found evidence that without guidance or structure, students often produced poor quality notes that included a verbatim transcript of what was said during class and often omitted important ideas and connections between concepts. Additionally, the act of taking notes could potentially be distracting if the note-taker has to concentrate on the motor act of writing instead of devoting all of his or her attention to the lecture (Peper & Mayer, 1986). While the distracting aspect of note-taking might not outweigh the benefits of generating notes, it likely complicates the overall picture. The complex relationship between note-taking ability, note-quality, and test performance is further complicated by students' own misperceptions of what benefits their learning.

In a study on meta-cognitive awareness, McCabe (2011) asked participants to choose the learning strategy that they would find most helpful for themselves and others in each of six scenarios. She found that participants generally did not choose the strategies that cognitive psychologists have consistently shown to be beneficial for recall. The only exception was in the case of content-generation, which entails connecting new information to already existing knowledge to generate thoughts or ideas, from which a majority of participants believed they could personally benefit. Students seem to at least have some awareness that generating their own content, such as by taking paraphrased or summative notes, can be beneficial for learning. This may or may not be reflected in their note-taking practices. While the generative effect may seem appealing in theory (Peper & Mayer, 1986; Ponce & Mayer, 2014), it may not come naturally to students (Bretzing & Kulhavy, 1979; Kiewra, 1989). In one of Mueller and Oppenheimer's (2014) experiments comparing laptop and handwritten note-taking, the researchers included instructions specifically asking students not to take verbatim notes while typing, but participants disregarded those instructions. It seems that students may not engage in the practices that cognitive psychologists argue are most beneficial for learning, which makes understanding how students actually think about and take notes crucial to an overall understanding of note-taking.

Student Perceptions of Note-Taking

Most students do not take an optimal approach to studying (see Bjork, Dunlosky, & Kornell, 2013 for a review of student approaches towards self-regulated learning) and understanding the relationship between how students study (how they process the product of note-taking) and their academic performance is outside the scope of this paper. The focus instead is on student approaches towards note-taking and whether the current practice reflects the dominant theories of note-taking described in previous decades.

It was not until 1994 that researchers developed a theory of note-taking that was based on the experiences of college students and how they perceived note-taking in terms of their approaches towards it and its perceived benefits (Van Meter et al., 1994). Through several rounds of structured interviews and focus groups, Van Meter et al. asked students about their goals for note-taking, the strategies they employed in taking notes, and how the method of information delivery impacts their practices. From this, the authors concluded that students generally reported being goal-oriented in their note-taking. Their goals included paying attention during class, taking notes as a way to facilitate understanding of content, and collecting information to be used for homework or exam study. Students' descriptions of the contents of their notes were highly varied and depended not only on the content of the class but on how information was presented. Instructors who provided outlines for their lectures and went through content at a slower pace facilitated the process of note-taking by allowing students to develop and utilize note-taking strategies. Instructors who were disorganized or spoke rapidly made it difficult for students to take notes in their preferred manner, which often led students to resort to other sources of information to supplement their notes.

Unlike the researchers who studied note-taking in controlled experiments, Van Meter et al. (1994) found that students did not see verbatim note-taking as problematic. Some of the students they interviewed indicated they believed that taking word-for-word notes ensured that their notes were accurate and did not preclude deeper processing of the information. Another important finding was that students perceived their own notes as more meaningful and useful to them than notes that were generated by others, which highlighted the complexity of the external storage component of note-taking.

The following work includes two components, which will be described separately. In the first part, semi-structured interviews were conducted with undergraduate students to further expand and update the theory crafted by Van Meter et al. (1994). In the second part, a survey was administered to a larger group of undergraduates to contextualize and expand the findings of part 1.

Part 1: Semi-structured interviews

Van Meter et al. (1994) crafted a theory of note-taking that took into account a diversity of circumstances, goals, and intentions, which was largely missing from the experimental research. Most of their findings likely remain valid for current college students, but two major technological forces have emerged since their writing that are likely to have had an impact on how students perceive note-taking: the usage of laptops in classrooms and the presentation of lectures through digital slides.

Computer-based slide presentations have been increasing in use and popularity among students since the early 2000's (Apperson, Laws, & Scepansky, 2006; Babb & Ross, 2009). A few studies have examined the impact of the usage of PowerPoint slides on exam performance and class behavior (Babb & Ross, 2009; Grabe, 2005), class attendance (Babb & Ross, 2009 found positive effects of slide availability on class attendance while Worthington & Levasseur, 2015 found no effect on attendance and an adverse effect on exam performance), and student perceptions of the course (Apperson et al., 2006).

The current study focuses specifically on how the practice of note-taking may be influenced by the availability of lecture slides. Grabe (2005) used survey and student online note usage records to examine the impact of making instructor-provided lecture notes available to students ahead of class on online note-usage and class attendance. The results indicated that most (74%) of the 183 students who participated in the study used online notes, often by printing them out before class, but the study did not determine whether the notes were used to supplement or supplant in-class note-taking. An examination of how the use and availability of lecture slides online affected student note-taking practices was generally absent from the aforementioned studies. The note-taking research does not adequately address this issue as well. Current trends in note-taking research may fill some of the gaps, but some gaps still remain between the theory described by Van Meter et al. (1994) and current student note-taking practices.

Several studies have compared laptop-based note-taking to handwritten with mixed results (Aragón-Mendizábal, Delgado-Casas, Navarro-Guzmán, Menacho-Jiménez, & Romero-Oliva, 2016; Beck, Hartley, Hustedde, & Felsberg, 2014; Bui, Myerson, & Hale, 2013; Mueller & Oppenheimer, 2014). Generally, typing led to more complete notes because participants, on average, could type faster than write (Aragón-Mendizábal et al., 2016; Bui et al., 2013). Mueller and Oppenheimer (2014, 2016) considered typing to take notes problematic because although typing may facilitate the creation of notes (external storage), it could lead to shallower processing of content. Other studies just focused on computer-based note-taking (Katayama, Shambaugh, & Doctor, 2005; Ponce & Mayer, 2014; Wei, Wang, & Fass, 2014) and found nuances around the different types of note-taking that one can do on a computer. Katayama et al. (2005) compared typing notes to copying-and-pasting them from the text being studied, and found that on a recognition test (multiple-choice) students who copy-and-pasted their notes performed just as well as those who typed their notes, but they did worse when trying to apply what they learned. Ponce and Mayer (2014) used eye-tracking to compare unstructured note-taking while reading a text to a more structured form of note-taking in which students filled in a sheet that had a structure for their notes such that they needed to go back into the text and find relevant information to complete the sheet. They found that when students were instructed to just take notes, they did so in a linear fashion, essentially taking notes in the same order that information was presented in the text they were reading. Wei et al. (2014) examined the impact of technology related distraction on computerized note-taking. They found that engaging in a computer enabled unrelated task, such as online-chatting had a negative impact on both note quality and test performance.

Information technologies, such as laptops and tablets, are a frequent presence in university classrooms and while their overall merits have been debated (e.g., Melerdiercks, 2005; Stephens, 2005) their influence on education is almost certainly undeniable. As in the Wei et al. (2014) study, the broader context of using technology in the classroom often comes up in studies on computerized note-taking. Some see laptop usage in classrooms as potentially benefiting class engagement without detrimentally affecting academic performance (Carstens, Watson, Williams, 2015). When appropriately integrated into the curriculum, computer usage has been found to increase student engagement with the materials (Barak, Lipson, & Lerman, 2006). Similarly, technology can be seen as a tool which eases the cognitive burden involved in note-taking by simplifying the process from writing, a complex motor program that involves the reproduction of the shape of each letter, to typing, a simpler motor program that involves the same action of pressing a button being performed for each letter (e.g., Kiefer & Velay, 2016). The simplification of the process, however, may come with a cost. Bjork (1994) described the effect of moderate difficulty in processing information while encoding it into memory as being desirable because the more effortful the processing, the more likely the information will be retained.

Other arguments also have been raised as to why laptop usage may be detrimental to learning. Much of the opposition to laptops in classrooms stems from environments in which laptop usage is unstructured and involves the issue of distraction and its relationship to poor academic performance (e.g., Fried, 2008; Ragan, Jennings, Massey, & Doolittle, 2014; Ravizza, Uitvlugt, & Fenn, 2017). Aside from the previously mentioned studies on computerized note-taking and broad examinations of the impact of online lecture slides on note-taking, there are notably few explorations of how technology has impacted the way that students engage in and perceive note-taking. The purpose of this paper is to provide an updated theory of note-taking based on college students' perceptions of note-taking in technology rich environments.

Method and Analysis

Fourteen students were interviewed about their note-taking practices and beliefs, and from the responses, two models of note-taker types were developed. The impact of technology was assessed in terms of both the method of note-taking and the method of content delivery. After the interviews were concluded, a survey was created to examine some of the themes described in the interviews on a larger scale. The survey is described after the interviews.

The methodology employed was similar to what was used by Van Meter et al. (1994), but smaller in scope and size. The purpose was to integrate modern perspectives into the theory they had already developed. Van Meter and colleagues used ethnographic interviews and focus groups to build a theory of note-taking by determining which questions were most relevant and using an iterative process to hone in on a few key concepts.

Based on the questions asked by Van Meter et al. (1994), a semi-structured interview protocol was created and approved by the Institutional Review Board. The interview protocol can be found in *Appendix C.* The first question asked participants to describe how they take notes in class. General areas that the questions touched upon included the reason why notes were taken in the way described, the purpose that the notes serve, the information that is generally included in the notes, and how the participant uses the notes that they have produced. Technology, particularly information technologies such as laptops and tablets, was discussed as it related to the answers provided by participants.

After the first few interviews, further questions were derived based on the responses that had been received. This procedure followed the constant-comparative method (Glaser & Strauss, 1967) in which data are analyzed as they are collected, and the interview protocol is updated to reflect the topics that participants seemed interested in discussing. This was done by comparing responses among early participants and looking for common themes. If multiple participants had mentioned a particular idea, later participants were asked questions related to that idea. For instance, most early participants had mentioned PowerPoint slides and having information available online, so subsequent participants were asked about how the usage and availability of PowerPoint slides impacted their note-taking if they did not mention it independently.

Participants recruited for the study were students at the large Midwestern university attended by the researcher. One of the goals of recruitment was to pull from different academic disciplines. Participants were all undergraduates at various stages in their programs with a variety of majors including psychology, industrial engineering, marketing, and communications. Recruitment was done through personal contact with the participants. Participants previously known to the researcher were recruited to facilitate trust and more willingness to discuss personal note-taking habits. Interview sessions lasted less than 10 minutes and were scheduled at the convenience of the participants. Some participants were familiar with the researcher's previous work on computerized note-taking, but were not familiar with the current study.

Interviews were done one-on-one and conducted in quiet spaces reserved for that purpose. Audio of the interviews was recorded and transcribed verbatim. After an interview was analyzed, ideas that were emphasized by the participant but not previously considered by the researcher were incorporated into the next interview. If one participant had described changing her methods of note-taking based on how much information an instructor posted online, the next participant was asked about how the information made available by the instructor impacted his note-taking methods.

Transcripts were initially read to determine what sort of information was present in participants' responses. Points that were mentioned multiple times or elaborated upon by participants were distilled into general themes. Themes that seemed to fit together within participants were clustered into categories of note-takers. Initial data coding consisted of three stages described by Strauss and Corbin (1990): open coding, axial coding, and selective coding. Open coding involved examining each transcript and looking for themes that fit into a particular category. The initial categories of interest were based on the theory described by Van Meter et al. (1994) and consisted of the following: how notes are taken, the purposes of note-taking, reasons for taking notes, what information is written down, and why notes are not taken on a laptop (or why notes are not written by hand if the participant took notes on a laptop). The goal was to saturate the categories such that additional participants were not saying new things that had not been mentioned before. Once the categories were saturated, the axial coding process connected the categories together such that how notes were taken was tied to the reason for taking notes which fit in to the purpose of taking notes, which informed the kind of information that was written down as well as why notes were not taken with a different medium. Once all of these connections were formed, a story emerged that involved two different types of note-takers who had more in common with each other than they did with participants in the other group of note-takers.

Results

Only one participant described typing as her primary form of note-taking, which made a comparison between handwritten and computer notes untenable. Most participants described why they did not take notes on a laptop, so this was included as a theme, but it overlapped between participants in both note-taker categories. All participants included a description of how the availability of lecture slides or notes online impacted their note-taking either for a particular class or generally.

Two categories of note-takers emerged from data analysis. The participants within each category touched upon similar themes when describing their purposes for taking notes and can be broadly thought of as those who emphasized the act of note-taking (the process-oriented group) and those who felt ambivalent towards the process but found notes useful as a reference (the process-ambivalent group). Out of the 14 participants who were interviewed, 10 fell into the first category and four into the second. *Figure 10* shows a summary of the responses of participants in both groups. The figure was created to display common response themes within each group and between the two groups. While both groups had different reasons for taking notes and different uses for their notes, there was much agreement between the two groups on how classroom technologies affect note-taking.

Process-oriented note-takers

The process oriented group (10 participants) emphasized the act of taking notes as important for their learning. In describing the primary purpose of note-taking, seven (70%) talked about how the act of taking notes helps them remember information, which aligns with the encoding hypothesis of note-taking. Examples of how participants described note taking include "I think just writing them out helps keep it in my memory even if I don't go back and look at it," "writing things down makes it stick a lot better in my head," and "when I write it down I'm more likely to recall it later." All participants in this category mentioned either remembering information or understanding it as motivations for taking notes in class. Only one participant in this group regularly took notes on a laptop; the rest wrote their notes by hand.

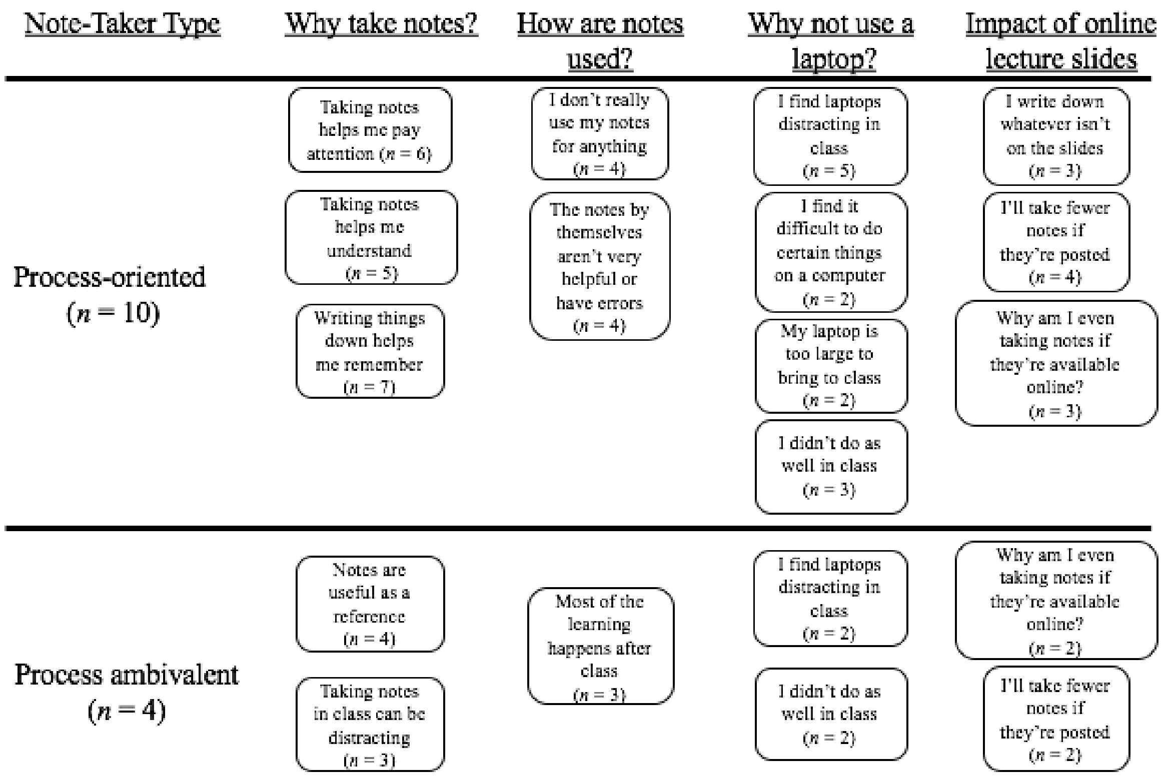

Figure 10. The response themes from two types of note-takers to questions about their note-taking habits.

Six of the participants (60%) in this group also emphasized the role of note-taking during class as a way to pay attention in class. When participants talked about the role their notes played in paying attention a couple of them said "I feel like I space out less if I'm writing down something," and "If I didn't take notes in class I'd fall asleep."

Participants in the process-oriented group had less to say about how useful their notes were outside of class. While four mentioned using their notes to study, several added a caveat such as "I don't review them too much," and "just notes aren't very helpful," and "I don't really use them themselves to study." One participant stated, "I don't even usually look at the notes I take," while another said, "sometimes my notes have errors in them so I'd be better off if I just looked online at their notes instead of trying to read through mine."

When describing the contents of their notes, participants varied greatly in what they wrote down as well as how they decided what information is important. Some jotted down "key words in bullet points" or "getting the general ideas down" while others wrote things down in their own words. Characteristics of content that were considered important for note-taking included "if the teacher has it written down," "for examples, I usually write everything down," and "if a teacher emphasizes it a lot and keeps repeating it over and over."

Regardless of the individual differences in note-taking contents, all of the participants in this group altered their note-taking habits based on whether their professors posted lecture slides online. The general consensus, as described by eight (80%) of participants in this group, was that the more information that was available online, the fewer notes they would take. Three participants described only writing information that was not on the slides: "whenever she says something that's not on the slide, I write that down" and "I write down whatever is not mentioned on the published slides." Four just described taking fewer notes: "I'll take a lot fewer notes if the professor posts their slides online all the time," "I can look it up later so I definitely don't take as in-depth notes," and "I haven't written as many notes in the last couple of years mainly because most professors are posting everything online." One even went so far as to say, "sometimes I think why am I taking notes if they're available on Blackboard?" The theme of writing down less information when that information is available elsewhere was fairly dominant throughout each conversation and was often brought up by the participant rather than the interviewer.

In regards to using their own technologies in class, six (60%) of the participants indicated that they had at some point tried to use a laptop to take notes, but only one participant stuck with it because she wanted to improve her typing skills. When the participants who wrote their notes by hand were asked why they did not use a laptop, most pointed to not wanting to be distracted (e.g., “I would get distracted a lot easier,” “I feel like it’d kind of distract me,” and “on the computer you’re more tempted to also look at other things”). Some mentioned the difficulties of trying to do certain things on a computer like making graphs or connecting concepts in a non-linear fashion. Others just said that their laptops were too big to bring to class.

Overall, the process-oriented group seemed fairly consistent in their views towards note-taking as a useful process that generated a somewhat-useful product. The contents of their notes may have varied based on the note-taker, the class, and the context, but all seemed to have altered the contents based on what information was made available by the professor outside of class.

Process-ambivalent

The remaining four participants did not have a strong focus on the process of note-taking and were considered process-ambivalent. One thing that they all had in common was their focus on notes as providing a reference. The process-ambivalent group emphasized the usefulness of notes as a product rather than the process itself. When describing their purpose for note-taking all of them said they their notes are mainly used as a reference either to later study or to use in completing homework assignments (e.g., “it provides more of a reference,” and “just mainly a reference”). The contents of their notes varied from “I usually try to write down word for word” to “I’ll write down some of the main ideas.”

When describing the process of note-taking, one respondent said that “they help me pay attention” but the other three had less positive things to say about the act of taking notes in class. One participant mentioned “not putting much thought” into note-taking and said that “a lot of it is just transcribing… and thinking about it later.” Another complained that “if I’m taking notes in class oftentimes I’ll miss some of what the professor says,” which echoed a similar complaint by a different respondent who said “I found the class where I have to scribble and take notes really quickly and also try to listen doesn’t really work for me.” Previous research on the relationship between individual characteristics and note-quality found that note-taking speed and sustained attention were important for note-quality (Peverly et al., 2014; Piolat et al., 2005) so it is likely that these factors influenced these respondents’ perceptions of the benefits of note-taking.

When asked about how they use their notes outside of class, process-ambivalent respondents were also mixed in their responses. One said “I usually just look at my notes to be like OK so we talked about this and then find it in the slides” while another indicated that most of the learning he engages in happens after class with the help of notes taken during class. One respondent mentioned not usually using notes for anything, but finding the slides posted online very useful. This respondent had described how when taking notes “I’m focused on trying to figure out what I’m gonna write and writing it fast enough,” which might make it harder to produce good notes while still paying attention to the content being covered. The notes produced under such circumstances are unlikely to be reliable, which would explain why the respondent expressed not using notes outside of class. It seems that students’ relationship with note-taking is complex and not easily categorized. Not all students take notes, and it seems that some who do are not necessarily doing so because they find it useful. These students are thus categorized as process-ambivalent.

When talking about why they do not use laptops to take notes, all four participants remarked upon the same issues that were described by the process-oriented group: laptops are distracting, can be difficult to use for some tasks, and can make it harder to pay attention and remember information. In describing the impact that the availability of notes online had on their note-taking, process-ambivalent respondents described seeing a redundancy between note-taking and note-having. All four described having PowerPoint slides available online as detracting from the need to take good notes (e.g., “I don’t take very good notes just cause he puts so much on the slides,” and “I used to take notes and then I realized he posted all of his lectures online” and “I would have to take notes for sure if it wasn’t posted online”).
While this group seems to have prioritized the product of note-taking over the function, their descriptions did not fit perfectly with the storage hypothesis of note-taking.

Discussion

The storage function of note-taking seems to have fundamentally changed with the increased usage of computer-based slide presentations in class and the availability of these slides online. This phenomenon has been previously described as it relates to note-usage (Grabe, 2005; Haynes, McCarley, & Williams, 2015). Grabe (2005) described how the majority of students in a large psychology lecture course accessed online notes prior to attending the class for which those slides were posted and how a sizable proportion of those students printed out those slides. What students did after printing out the online slides was not described. Haynes et al. analyzed the contents of students’ notes taken during a lecture presented through PowerPoint slides and found that notes included less relevant information than what was available on the slides. The responses gathered in the present study provide some insight into how student note-taking behavior may change when they are provided with online lecture slides.

Prior to the widespread usage of the Internet in academic contexts, students generally had limited resources, aside from textbooks (which are not used in every class) from which they could study for exams. They either had to be present during class to take notes so they could study from those or they had to borrow someone else's notes. The introduction of learning management systems such as Blackboard or Canvas and the widespread use of PowerPoint slides to present lecture contents made it possible for students to obtain the information covered in the lectures without being in attendance or relying on someone else's notes (e.g., Grabe, 2005; Worthington, & Levasseur, 2015). Based on the responses of the participants that were interviewed, the value of note-taking seems to have shifted from an open debate between encoding and storage to an emphasis on encoding and a reliance on multiple sources of information for storage.

The process-oriented participants seemed to align with the encoding hypothesis of note-taking. They emphasized the importance of the process of note-taking and how it can help them pay attention in class and learn the materials. Most of them discounted the external storage component of note-taking, which is likely due to the existence and accessibility of other materials, such as lecture slides, from which they can study. Their reasons for taking notes and the contents of their notes were varied, which is consistent with the findings described by Van Meter et al. (1994). While only one participant consistently took digital notes, many of the participants in this group had tried, at some point, to take notes on a laptop. Their reasons for switching back to handwriting their notes echoed the concerns of

Fried (2008), Ravizza et al. (2017), and Carstens et al. (2015). They were aware of the potential for distraction that laptops presented and some even connected negative learning outcomes with laptop usage. Based on the literature showing the negative impacts of unstructured laptop usage in classrooms one might expect students to be unaware of how laptop distractions impact their learning, but that seems not to be the case. Participant responses also shed some light on the effect that posting slides online can have on students note-taking habits, an effect which previously had been described through measures of performance and online lecture slide access (Babb & Ross, 2009; Grabe, 2005; Worthington & Levasseur, 2015). The current study provides a clearer picture of the thought-processes students may have around the use and availability of online lecture slides.

The process-ambivalent participants were a lot less enthusiastic about the note-taking process and seemed to take a more pragmatic approach. These participants seemed to know exactly what they wanted to get out of their note-taking and focused on the product rather than the process itself. As long as the information they needed was available somewhere, it did not seem to matter whether they took notes or not.

Part 2: Survey

To determine whether some of the themes identified in the interviews were representative of a larger proportion of the student body, survey questions were designed based on common themes that emerged when participants were asked about their purpose(s) for note-taking. When asked about their purposes for note-taking, the participants who were interviewed generally did not describe only one purpose for taking notes. Participants who responded to the survey questions were similarly given the opportunity to indicate multiple purposes for their note-taking. The survey questions were part of a larger survey comprised of questions from multiple researchers, so there was a limit of four questions that any individual researcher could ask.

Method

Participants

The survey was completed by 263 undergraduate students (60 males, 203 females) in exchange for course credit in a psychology course. The survey consisted of four questions and was part of a larger online survey comprised of questions from multiple researchers.

Materials and procedure

The survey items and alternatives are shown in *Table 5*.

Table 5. Survey questions and answer options. Each column contains the answer choices provided for the question listed in the top row.

Q1. How do you usually take notes in class?	**Q2. What purpose do your notes serve? (Choose all that apply)**	**Q3. Do your instructors post slides online?**
a. Writing on paper	a. They help me pay attention in class	a. None of them do
b. Typing on laptop or tablet	b. They help me learn the materials during class	b. Some of them do
c. Writing on tablet	c. I use them to study alongside other materials (e.g., slides provided by the instructor)	c. Most of them do
d. Other method not listed	d. I study my notes by themselves	d. All of them do
e. I do not take notes in class		

Participants completed the survey online.

Results

The majority (61%) of participants (n = 161) indicated that they usually take notes by writing on paper and the next most common method (35%) was typing (n = 92). Two indicated using other methods and five said they did not take notes at all. Participant responses to the question about what purposes their notes serve are shown in *Table 6*. The fewest participants indicated that they studied their notes by themselves. Based on participant responses to interview questions as well as the survey results, students seem to rely on the process of note-taking to pay attention in class and help them learn the materials during class.

Table 6. Participant responses to 'What purpose do your notes serve? (Choose all that apply)'

Purpose of note-taking	Participants (% of total)
They help me pay attention in class	217 (82%)
They help me learn the materials in class	194 (73%)
I use them to study alongside other materials (e.g., slides provided by the instructor)	206 (78%)
I use them to study by themselves	77 (29%)

Much less emphasis seems to be placed on the product of note-taking, at least on its own. When asked about the availability of lecture slides online, the majority of respondents indicated that some (*n* = 123) or most (*n* = 114) of their instructors post lecture slides online. Seven students indicated that none of their instructors post slides and 19 students indicated that all of their instructors do. It seems that the practice of using slides and posting them online lectures is a common practice among instructors at the large Midwestern university where this research took place.

The survey responses largely mirrored what interview participants had described. More than half (61%) of respondents indicated they usually take notes by hand, which is surprising considering the relative prevalence and ease of laptop usage. Most (82%) of participants agreed that taking notes helped them to pay attention in class and/or helped them learn the materials during class. Fewer than a third of participants (29%) described studying their notes without relying on supplementary materials. This result fit with the majority of interviewed participants who emphasized the importance of the note-taking process. Overall, the themes described by the interview participants seemed to resonate with the larger group of students. Although no questions were asked about how the availability of lecture slides online impacted note-taking, it is clear from the survey that most students have access to lecture slides for at least some of their classes, and it is clear from the interview participants that this availability has an impact on their note-taking habits.

General Discussion

From the interview participant responses and survey data, an updated view of note-taking emerged. Several of the themes described by Van Meter et al. (1994), such as using note-taking as a way to pay attention in class or learn the materials and viewing notes as a reference if not a primary study resource, still resonate with modern students, but the practice of note-taking has not remained unaffected by technology. Many (57% or 8/14) of the interview respondents had tried to take notes on a laptop but ultimately decided against it. Among the broader student population who responded to the survey, a much larger proportion (35%) indicated they usually take notes on a laptop. It is likely that the students in this category have had similar experiences to the students who were interviewed, but have either decided to continue using laptops regardless or have found ways around the problems described by interview participants such as the presence of distractions and the difficulty of drawing graphs and making figures.

Because the findings corresponded well with the results reported by Van Meter et al. (1994), it appears that student perceptions of note-taking have not radically changed as technology has become more available. The note-taking purposes described by interviewed participants and confirmed on a wider scale by survey participants are largely the same as those described in the earlier work. However, there seems to have been a shift in emphasis from the note-taking product to the process itself, which is heavily influenced by the way that information is presented in class. Evidence for this influence can be found in both the study by Van Meter et al. (1994), where participants indicated that their note-taking habits were based in part on the level of organization of each lecture, and the responses of participants interviewed in the current study. All ten of the process-oriented participants described basing the contents of their notes on what information is presented and how. Five specifically mentioned lecture slides and basing their note-taking on what is or is not mentioned on the slides. The biggest difference found in the present research is that students may see the use and availability of slides not just as a method of organizing information, but rather as either a supplement to or replacement for their own notes. Most (10 out of 14) of the students interviewed described the process of note-taking as valuable to their understanding and retention of information. Most (12 out of 14) of them described note-taking as having an inverse relationship with the availability of information online. The more information that was available for them online, the less important their own note-taking became regardless of their goals for taking notes.

Several explanations exist for how the availability of lecture slides online affects note-taking. One of these explanations involves the fluency effect, which occurs when information that is easy to process is seen as easy to learn, so less effort may be devoted to actually learning that information (see Alter & Oppenheimer, 2009 for a review of the fluency effect). When students see information on a slide, it is generally presented in a manner that is easy to read, which may lead to the interpretation that the information is easy to understand and additional processing effort is not required. Another explanation for why students take fewer and less detailed notes when PowerPoint slides are available for them online is that they view the act of taking notes on the contents of a slide as redundant. If the information is already written down somewhere, they can access it, so there is no point in repeating that information in their notes. This could be seen as a form of cognitive offloading, where external objects can be viewed and treated as extensions of the brain (see Risko & Gilbert, 2016 for a review on cognitive offloading). Cognitive offloading can be beneficial in that it can expand human capabilities by taking on some of the mental burden of completing a task and freeing up the cognitive resources that would otherwise be devoted to that task. It can also be detrimental if used to supplant rather than supplement cognitive processes such as learning. If information is readily available externally, the motivation to store and maintain that information in internal memory may decline. Regardless of why the availability of slides impacts note-taking, it is clear that it does.

Author Biases, Limitations, and Future Directions

It should be noted that the author is herself a graduate student and regularly engages in note-taking in class. The author generally takes handwritten notes and believes this method of note-taking to be more beneficial for paying attention in class and retaining information. When the author has used a laptop in class, it has frequently been for the purpose of engaging in class-irrelevant activities. The potential for distraction that comes with using an internet-enabled laptop computer in class is well known to the author and may have contributed a bias in reporting about the effects of technology on in-class behavior. Initially the purpose of the study was to compare between handwritten and typed note-taking practices among students, and it is possible that the author's own perspective on the subject could have influenced the way the she interacted with participants and the questions that were asked. Some of this bias was mitigated by starting with an open-ended question: "tell me about how you take notes in class" and using participant responses to guide the rest of the interview. The author takes a critical approach toward technology but has made an effort to include research articles from a variety of perspectives on classroom technology usage.

While attempts were made to interview participants of different backgrounds and grade levels, it is likely that the sample described was biased towards highly motivated students because the researcher was familiar with participants through their work as research assistants. Participants were generally conscientious students who consistently took notes in class and were willing to discuss their habits with a researcher. However, the survey was administered to a broader and more diverse group of students and largely corroborated the interview findings.

Future research on note-taking should take into account the disruptive effects of using computer-based slides to present a lecture and posting those slide online for students to access. Students may see the usage of computer-based slides during lecture and their availability online as a desirable outcome, but that desirability may just be a manifestation of the fluency effect, which generally leads to overestimations of knowledge and less effort devoted to learning. If instructors want students to engage in the effortful process of learning, they may benefit from a better understanding of how the use and availability of slides affects how students approach learning. While some research has been devoted to exploring the positive and negative effects of laptop usage on learning, laptops are not the only disruptive technology that has been introduced into college classrooms. The research on the impact of online lecture slide availability has answered some questions about the impact of slide availability on attendance, student attitudes towards the class, exam performance, and whether or not students view the posted slides before class (Apperson et al., 2006; Babb & Ross, 2009; Grabe, 2005; Haynes et al., 2015; Worthington & Levasseur, 2015). The present study added student perspectives on the influence of online lecture slides availability and how it has impacted their note-taking. Future research may further investigate, on a larger scale, how the availability of lecture slides has impacted the way that students approach note-taking and whether the availability of accurate instructor-generated notes may benefit those students who find in-class note-taking to be distracting.

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CHAPTER 4: HOW GOOD ARE YOU AT TAKING NOTES?

Abstract

In Chapter 2, participants listened to facts and took notes on a computer where they were saved. The act of choosing where to save notes rather than having them randomly assigned led to better memory for folders where notes were saved than for facts when the facts were hard. Chapter 3 examined students' note-taking habits and found that most of the students who were interviewed prioritized the process of note-taking and that a majority of students surveyed take notes by hand and believe they learn from taking notes. The purpose of Chapter 4 was to compare the effects of handwritten and typed note-taking on memory for the facts used in Chapter 2 and the folders where notes were saved. Participants either typed and saved notes on a computer or took notes by hand and saved them in hanging folders. Memory for facts and folders was marginally better for participants who wrote their notes by hand, but participants who handwrote their notes also spent more time doing the task. Participants also made judgments of difficulty for each fact and average participant judgments reflected two separate distributions of fact difficulties indicating that there were easier and harder facts.

In Chapter 3, undergraduate interview and survey respondents indicated that a large proportion of them took notes by hand and considered the process of note-taking important for either paying attention or remembering information. It was unclear, however, whether students approached information differently when they took notes by hand or on a computer. In Chapter 2, two experiments were described in which participant memory for information and for where that information was saved on a computer were tested. The experiment described here combines research concepts from Chapters 2 and 3 to examine whether participants take different approaches to note-taking and note-saving when they write their notes by hand and save them in physical folders vs. when they type and save their notes in computer folders. As in Chapter 2, the task involves memory for information or where to find it but with a focus on comparing between handwritten and laptop-based note-taking.

Although the modern college classroom may look different from the college classroom decades ago due to technological advancements, note-taking is still a commonplace activity among college students. The importance of note-taking has been established through several decades of research that examined the impact of both the practice of note-taking (Jansen, Lakens, & IJsselstein, 2017; Kobayashi, 2005) and its product (Annis & Davis, 1975; Di Vesta & Gray, 1972). The growing availability of information through technologies (Baar, Pennycook, Stolz, & Fugelsang, 2015; Heersmink, 2016; Ward, 2013) may have shifted the focus away from notes (i.e., the product of note-taking) and towards the process of note-taking itself, because notes are now only one of many available sources of information.

The process of note-taking entails comprehending the content that is being presented and translating it through physical action into a written or typed record (Peverly, Garner, & Vekaria, 2014). In order to successfully generate notes, the note-taker must be able to maintain the information that is being presented in working memory while writing it down or typing it (Piolat, Olive, & Kellogg, 2005). Because of this, being able to generate notes quickly (either through fast handwriting or typing speed) may be important for creating more detailed and thorough notes (Bohay, Blakely, Tamplin, & Radvansky, 2011). For example, in a study on note-taking in university classrooms, Kim, Turner, and Pérez-Quiñones (2009) found that while the majority of their participants preferred taking notes by hand, those who preferred typing their notes cited the speed and neatness of typed notes as reasons for their preference.

Research comparing the impact of handwritten and typed note-taking on learning has generated mixed results. While some researchers have argued that the speed and efficiency of typing positively impact note quality (Bohay et al., 2011) and lead to improved memory for content (Bui, Myerson, & Hale, 2013), others have argued that the relative speed and efficiency of typing lead to shallower processing of content and worse memory for content (Aragón-Mendizábal, Delgado-Casas, Navarro-Guzmán, Menacho-Jiménez, & Romero-Oliva, 2016; Mueller & Oppenheimer, 2014). The comparisons have involved asking participants take notes on a wide variety of topics: a lecture (Bohay et al., 2011; Bui et al., 2013), an educational video (Mueller & Oppenheimer, 2014), a list of words (Aragón-Mendizábal et al., 2016), and a text passage (Bohay et al., 2011). After taking notes, participants were given a test on the content they had learned. The types of tests were as varied as the methods of content delivery, making a direct comparison between studies difficult. In some of the experiments (e.g., Bohay et al., 2011; Bui et al., 2013; Mueller & Oppenheimer, 2014) participants were able to review their notes prior to the test, but in others (e.g., Aragón-Mendizábal et al.,2016), they were not because the focus was entirely on the encoding side of the note-taking process. None of the studies was concerned with how the later availability of the information, either in the notes that were taken or in some other way, impacted how participants approached the information they were tasked with learning, a question that was examined in Chapter 2.

Prior research on the impact of the increasing availability of information due to the proliferation of information technologies points to a willingness to rely on external information in lieu of internal memory (e.g., Dix, Howes, & Payne, 2003; Dunn & Risko, 2016; Heersmink, 2016; Risko & Dunn, 2015, Sparrow, Liu, & Wegner, 2011). Research on cognitive offloading, the process by which individuals supplement or supplant cognitive processes with technology, suggests that the purpose of offloading cognition is to decrease the amount of mental effort required to successfully complete a task (see Risko and Gilbert, 2016 for a review). Decreasing the amount of information held in memory is also helpful because working memory has a limited capacity, where working memory is defined as the currently available information on which cognitive processes, such as rehearsal, can be performed (e.g., Baddeley, 1986). The dominant hypothesis that explains the limited capacity of working memory is that new information entering working memory causes interference with memory for information that was already in memory as well as information that has yet to enter working memory (see Oberauer, Farrell, Jarrold, & Lewandowsky, 2016 for a review on the theories that may explain the limited capacity of working memory).

The purpose of the current study is not only to make a comparison between the effects of handwritten and typed note-taking on learning, but also to examine the impact that the creation and storage of handwritten and typed notes has on participants' willingness to store information internally. In the case of participants taking notes and saving them in folders, the existence of an accessible external memory record may influence the information on which the limited working memory capacity is used. According to the soft-constraints hypothesis, put forth by Gray, Sims, Fu, and Schoelles (2006), people try to optimize the completion of a task by using a combination of internal (mental) and external (technological) processes that minimize performance costs (in terms of time it takes to complete a task as well as the effort involved) while still achieving the expected outcome. How much information people choose to store in internal memory relative to how willing people are to rely on external resources may relate to this optimization. If information is relatively easy to process, people may choose to store it internally because it takes less time and effort to remember it than it would to write it down. If information is difficult to remember, people may try to rely on being able to find that information externally rather than commit it to internal memory.

In a study on the impact of Internet access on participants' willingness to use their internal memory, Ferguson, Mclean, and Risko (2015) found that when participants who were tasked with answering general knowledge questions were allowed to look up information on the Internet, they were more reluctant to volunteer responses from memory, opting instead to rely on externally available information. The authors concluded that participants were less confident in their own internal knowledge when they could access that knowledge externally. This phenomenon could be related to how complex or difficult the information in question seems to be. When information seems relatively easy to process, people tend to be more confident in their ability to remember that information, which may lead to an increased reliance on internal memory, a phenomenon called the fluency effect (see Alter & Oppenheimer, 2009, for a review). Combining people's willingness to rely on external information when information seems difficult to learn and the confidence that comes with judging fluently processed information as easy to learn, the question arises of what impact technology (and easy information access) might have on one's willingness to rely on either internal memory or external storage devices.

In Chapter 2, internal and external memory storage were examined in two experiments. The first experiment looked at participants' memory for facts and where notes on facts were saved when participants believed they would have access to their notes and when participants believed they would not. There was no effect of belief. The second experiment looked at the impact that choosing where to store notes on facts had on memory for facts and the folders where notes were saved. The results indicated that the act of choosing where to save notes led to worse memory for facts, particularly the hard facts, and better memory for folders. When the facts were hard to remember, participants who were able to strategically distribute their notes among the folders practiced off-loading in which they made a tradeoff that allowed them to remember where they could find their notes (i.e., remember the folders) at the expense of remembering the facts themselves. Participants in both of the experiments in Chapter 2 took and saved their notes on a computer. In Chapter 3, the majority of participants who were interviewed about their note-taking habits indicated that they usually took notes in class by hand rather than on a laptop. The purpose of the present study was to explore the off-loading phenomenon described in Chapter 2 by comparing participants who took and saved notes on a computer to those who took notes by hand and saved them in physical folders.

The memory task was nearly identical to that employed in Chapter 2 except that all notes were saved: participants listened to facts, took notes, and chose where to save the notes for each fact with the belief that they would be tested on the facts and that they could access their notes if they could remember in which folder they were saved. Half of the participants took notes on the computer and saved them to computer folders, just as in Chapter 2. Half of the participants wrote their notes by hand on note-cards and placed each note in one of six physical folders in a hanging folder file that was located next to the computer monitor on which participants received written instructions.

It was hypothesized that participants in the writing condition would have better memory for facts than participants in the typing condition. This hypothesis was based on earlier findings that participants who wrote their notes by hand had better memory for the information on which they took notes (Aragón-Mendizábal et al., 2017; Mueller & Oppenheimer, 2014) and on the idea of desirable difficulties, which suggests that the more difficult or effortful it is to learn something, the more likely one is to remember it (Bjork, 1994). In their explanation for why participants who took notes by hand outperformed participants who typed their notes on a test of what they learned from an educational video, Mueller and Oppenheimer (2014) argued that participants who took notes via laptop were more likely to be engaging in mindless transcription. Typing, in terms of the physical action, is generally seen as easier and more efficient than handwriting (e.g., Bohay et al., 2011; Kiefer & Velay, 2016; Kobayashi, 2005). While handwriting requires the use of fine motor skills to recreate the shape of each individual letter as it is written, typing merely involves the pressing of identically shaped keys that are generally distinguished only by location on the keyboard (Kiefer & Velay, 2016). Note-taking requires keeping information in mind while performing the physical action of transcribing it and the longer and more effortful the task of transcription, the more time information must be kept in mind (e.g., Peverly et al., 2014). Therefore, the hypothesis that participants in the handwriting group will have better memory for the facts on which they take notes is based on the idea that these participants will have to maintain the information in working memory long enough to reproduce each letter on a note-card.

Fact difficulty, as determined by the experimenter, influenced fact and folder memory in both experiments in Chapter 2. In the current experiment, after taking notes, participants were asked to give a difficulty rating for each item. This rating allowed for a more individualized examination of the relationship between fact difficulty and memory for both facts and folders. If participants chose to rely on their notes when the facts were difficult, they should have better memory for folders than facts when they rated the facts as more difficult and better memory for facts when they rated them as easier.

Method

Participants and design

There were a total of 84 undergraduate participants (50 females) from Iowa State University. They completed the study for course credit. The average age was 19.4 (SD = 1.93). Forty of the participants completed the writing task and 44 completed the typing task. The typing task took between 35 to 50 minutes and the writing task took between 50 and 70 minutes.

Stimuli and materials

Stimuli were the same 36 facts that were recorded and used for the experiments in Chapter 2. The cues to each fact provided during study and at test were also the same. All 36 facts and cues are provided in *Appendix A*. The audio stimuli were created using the Apple text-to-speech program on a MacBook Air running macOS 10.10.2. The voice used was Allison and the play speed was slightly slower than normal. Each statement was recorded using Audacity software (Audacity Team, 2012. Audacity® Version 2.0.0). Participants heard the facts through a pair of over-ear headphones; they were not provided with written versions of the facts, but the cue associated with each fact was displayed on the computer monitor as they heard it and were taking notes on each fact. The same cues were also used during the test phase to elicit recall. The task was programmed and presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Participants were provided with written instructions presented in a black font centered on a white background on the computer monitor. Everything was presented in a black font, including the names of the folders.

For the typing condition, a stack of blank note cards was provided next to the keyboard, along with a pencil and a hanging folder organizer containing six identical grey folders, each with a plastic tab labeled with names of colors in the same way as those in the typing task. Participants were also provided with a strip of paper on which the six folder names were printed. This was used by participants to keep track of how many notes were in each folder. Photographs of the writing task are provided in *Appendix D*.

Procedure

Participants were informed, via written instructions presented on a computer screen, that they would be listening to 36 statements, that they would have the opportunity to take notes on each fact while listening to the fact, and that a cue for the fact would be displayed while this occurred. They would then be asked to choose a folder in which to save the notes. The names of the folders were colors of the rainbow: RED, ORANGE, YELLOW, GREEN, BLUE, and PURPLE. Participants were informed that they would have to spread the notes evenly over the six folders and that they would have to keep a tally of how many notes they had saved in each folder on a slip of paper that was provided.

Typing task

After initial instructions, participants in the typing condition were then provided a practice trial during which they listened to a statement, typed notes on that statement, and saved the notes in the folder of their choice by pressing the number on the keyboard that corresponded with the name of their chosen folder. During practice, the count of facts in each folder was zero and was displayed next to the names of the folders. After this practice study trial, participants were informed that they would later be given a cued recall test for the facts during which they would see the same cues that they had seen when they were taking the notes for each fact. After the practice study trial, any questions about what would occur on a trial were answered. Next, an example test trial was shown during which the participants were informed that if they wanted to use their notes during the test, they would have the opportunity to view the note associated with a particular cue if they could correctly recall the name of the folder in which they saved the relevant note. Participants were shown an example in which they were directed to type in the name of the folder where they had saved their practice note and were then shown the note they had saved. This note was available as participants answered the recall question which was "What is the statement you heard about [cue]?"

After the practice trial, any questions were answered. Participants then completed the study phase, which consisted of 36 trials. During each trial, after taking the notes but before selecting a folder, participants were asked to type in a rating indicating the difficulty of the fact on a scale from 1-10 with 1 indicating that the fact was as easy as it could be and 10 indicating that the fact was as difficult as it could be. A count of how many notes were in each folder was displayed at the time the folder selection was made.

Writing task

After initial instructions, participants in the writing group engaged in a practice trial in which they listened to a statement and took notes on a note-card. After taking the note, participants were instructed to flip the index card over and to write down the cue as well as a difficulty rating for the fact. The participants were then instructed to place the index card in one of six hanging folders in the folder stand next to the computer monitor and then to make a tally mark by the folder name on the tally sheet. After the practice study trial, any questions about what would occur on a trial were answered. Next, participants were shown an example test trial. Participants saw "What is the statement that you heard about [cue]?" and the research assistant asked them to name the folder where they had just placed their notes. If they correctly named the folder, the assistant removed the card from the folder, confirmed that the appropriate cue was written on it, and handed it to the participant.

After the practice, any questions were answered. Participants then completed 36 study trials.

Test phase

The test phase, which used the monitor and computer keyboard, was the same for both the typing and writing group. Upon completing the study phase, the participants were informed that nobody would actually be allowed to use their notes during the test phase. The test phase consisted of 36 cued recall trials during which participants were asked to recall, as accurately as possible, the statement associated with a cue presented on the monitor. Participants were then asked to recall the folder in which they saved the notes associated with that cue. After completing the test phase of the experiment, participants were asked the following questions: "What strategy did you use to determine which note went into which folder?" and "What did you focus on trying to remember?" Research assistants were instructed to write down participant responses as they were given.

Results and Discussion

Recall results are presented followed by consideration of note quality, as was done in Experiment 2. These analyses are followed **by** more exploratory analyses of the items and participant strategies.

Fact and folder recall by task type

<u>Scoring</u>

Fact recall was scored on a binary scale by determining whether the statement typed by the participant during the recall test contained the idea units relevant to the fact. Rules were devised to disambiguate some of the facts for consistent scoring. Idea units and rules for scoring can be seen in *Appendix E.* Fact recall was scored by two independent raters and interrater agreement was 99%, so scoring was considered reliable. Folder recall was scored by comparing folder recall responses to folders chosen during the study phase. Typos and misspellings were accepted.

As was done in Chapter 2, the proportion of facts and folders that participants recalled was examined with a 2 (Task Type) x 2 (Difficulty) x 2 (Recall Content) ANOVA. Means are shown in *Figure 11.* Main effects and interactions are shown in *Table 7.*

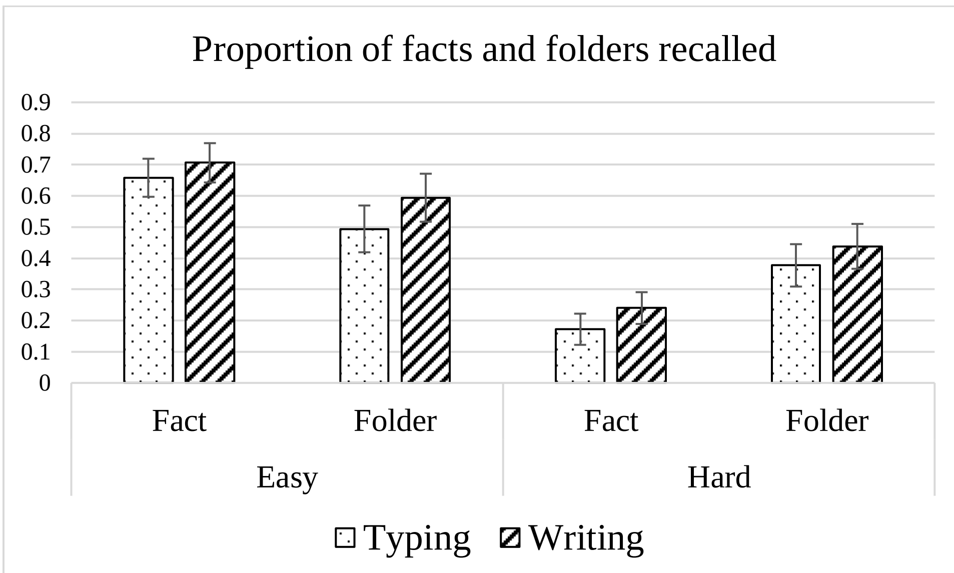

Figure 11. Proportion of facts and folders and folders recalled by participants. Error bars represent 95% confidence intervals.

Table 7. 2 (Task Type) x 2 (Difficulty) x 2 (Recall Content) repeated measures ANOVA.

Source	SS	df	*MSE*	*F*(1,82)	*p*	Partial η^2
Task type	.34	1	.34	3.77	.056	.04
Difficulty	7.37	1	7.37	446.19	< .0001	.85
Content	.13	1	.13	2.36	.13	.03
Task type x Difficulty	.00	1	.00	.00	.995	.00
Task type x Content	.01	1	.01	.09	.77	.00
Difficulty x Content	2.05	1	2.05	136.75	< .0001	.63
Task type x Difficulty x Content	.02	1	.02	1.56	.22	.02
Error	1.23	82	.02			

As found in both experiments in Chapter 2, there was a main effect of difficulty, with better memory overall for easy facts (*M* = .61, *SE* = .02) than hard facts (*M* = .31, *SE* = .02), but also as in those experiments, an interaction between difficulty and content was found. When the facts were easy, participants recalled more facts (*M* = .68, *SE* = .02) than folders (*M* = .55, *SE* = .03). When facts were hard, participants recalled fewer facts (*M* = .22, *SE* = .02) than folders (*M* = .41, *SE* = .02). This pattern of results was also found in Chapter 2 for participants in both groups in Experiment 1 and the choice group in Experiment 2 and indicates that when participants are tasked with choosing in which folder to save their notes, they can remember more of the easy facts and more of the hard folders. The harder facts were harder to recall than the folders associated with those facts.

Participants in the writing group recalled numerically more overall (*M* = .49, *SE* = .02) than participants in the typing group (*M* = .43, *SE* = .02), and the difference was marginally significant, $p = .055$ with a relatively low partial η^2 compared with other measures. It is common practice among researchers to refer to p-values falling between .05 and .10 as marginally significant (Prittschet, Powell, & Horne, 2016). Somewhat better performance in the writing group makes sense because, as indicated in the method section, the writing version of the task took longer than the typing version. Writing and physically placing notecard in folders is more effortful and time-consuming and this may contribute to better memory. Partly because of this reasoning, it was predicted that writing participants would have better memory for facts. Direct comparisons did not show a difference in recall for easy facts between the writing group (*M* = .69, *SE* = .03) and the typing group (*M* = .65, *SE* = .03), $t(82) = .9$, $p = .37$. The prediction was supported for hard facts. Participants who wrote their notes by hand recalled more hard facts (*M* = .25, *SE* = .03) than participants who typed their notes (*M* = .18, *SE* = .02), $t(82) = 2.01$, $p = .047$.

Note quality

As in Experiment 2 of Chapter 2, note quality was analyzed by counting the idea units present in each note. Each note was scored according to the proportion of idea units present. The idea units used to score both fact recall and note quality are included in *Appendix E.* Two independent raters scored note-quality for 10 of the participants and agreement between them was 98.7%, disagreements were resolved and one rater scored the remaining participant notes. Note quality was analyzed with a 2 (Task Type) x 2 (Difficulty) repeated measures ANOVA. Means are shown in *Figure 12.* Main effects and the interaction are shown in *Table 8.*

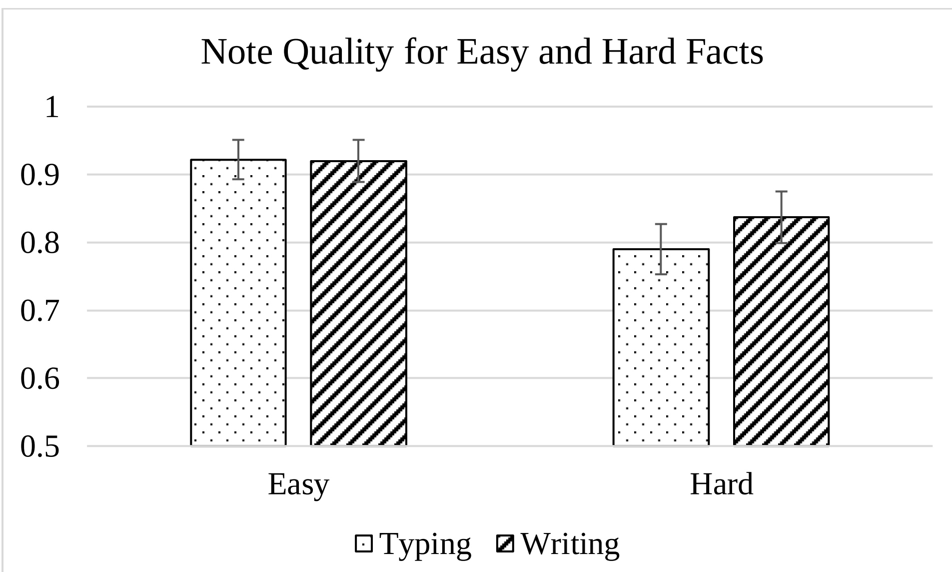

Figure 12. Note quality for easy and hard facts. Error bars represent 95% confidence intervals.

Table 8. (Task Type) x 2 (Difficulty) repeated measures ANOVA for note quality.

Source	SS	df	*MSE*	*F*(1,82)	*p*	Partial η^2
Task Type	.02	1	.02	1.15	.29	.01
Difficulty	.48	1	.48	86.53	< .0001	.51

Task Type x Difficulty	.03	1	.03	4.63	.03	.05
Error	.46	82	.01			

As found in Chapter 2, there was a main effect of difficulty, in which note quality was higher for easy facts (*M* = .92, *SE* = .01) than for hard facts (*M* = .81, *SE* = .01). This finding is consistent with the idea that the hard facts were difficult to maintain in working memory long enough to write or type notes for them even when notes were being taken while listening to the facts. There was also an interaction between task type and difficulty. When facts were easy, participants who typed their notes had notes of comparable quality (*M* = .92, *SE* = .02) to participants who wrote their notes (*M* = .92, *SE* = .02). When facts were hard, however, participants who typed their notes had lower quality notes (*M* = .79, *SE* = .02) than those who wrote their notes (*M* = .84, *SE* = .02). This might be because writing notes takes more effort than typing notes so if the act of taking notes is going to be effortful it makes sense to take better notes. This is consistent with previous research that found lower quality notes among participants who typed their notes compared to participants who wrote their notes (Mueller & Oppenheimer, 2014). To the extent that note quality is related to memory, these note quality differences fit with the recall results showing better performance for those in the writing condition. In fact, the overall note quality and fact recall correlation was $r(34) = .35$. The correlation is due almost entirely to the hard facts: for hard facts the correlation was $r(16) = .38$; for easy facts, the correlation was $r(16) = .21$ and was not significantly different from zero.

Item analysis

As expected and as found in the experiments of Chapter 2 and the current experiment, fact difficulty has a large impact on performance. Difficulty thus far, however, has been a binary variable determined by the experimenter. In the current experiment, participants judged the difficulty of each fact after the fact had been heard and the notes taken.

Objective difficulty and rated difficulty were determined for each of the 36 items. Objective difficulty was the proportion of total participants (regardless of task type) who correctly recalled the item. The lowest performing fact, “Gamma spectroscopy is the study of the energetic transitions in atomic nuclei” was correctly recalled by 1.2% of participants. Six facts, included the aforementioned fact, were recalled by fewer than 10% of participants (around 8 people). The highest performing fact, “North Dakota is the only state that has never had an earthquake,” was correctly recalled by 88% of participants. Seven facts were recalled by more than 75% of participants.

The lowest average difficulty rating for a fact was 2.4 (“elephants are the only mammal that can’t jump”) and the highest average difficulty rating was 7.5 (“Parkinson’s disease involves major loss of dopaminergic cells in the substantia nigra”). The distribution of difficulty ratings can be seen in *Figure 13* as a function of a priori categorization as hard or easy. The initial categorizations of easy and hard were explained in Chapter 2. The distribution is bi-modal, which is what was expected with the inclusion of easy and hard facts. As can be seen in *Figure 13*, although two of the “difficult” facts were judged as easy in the ratings, there is little overlap between the two categories. The initial categorizations were reasonably accurate.

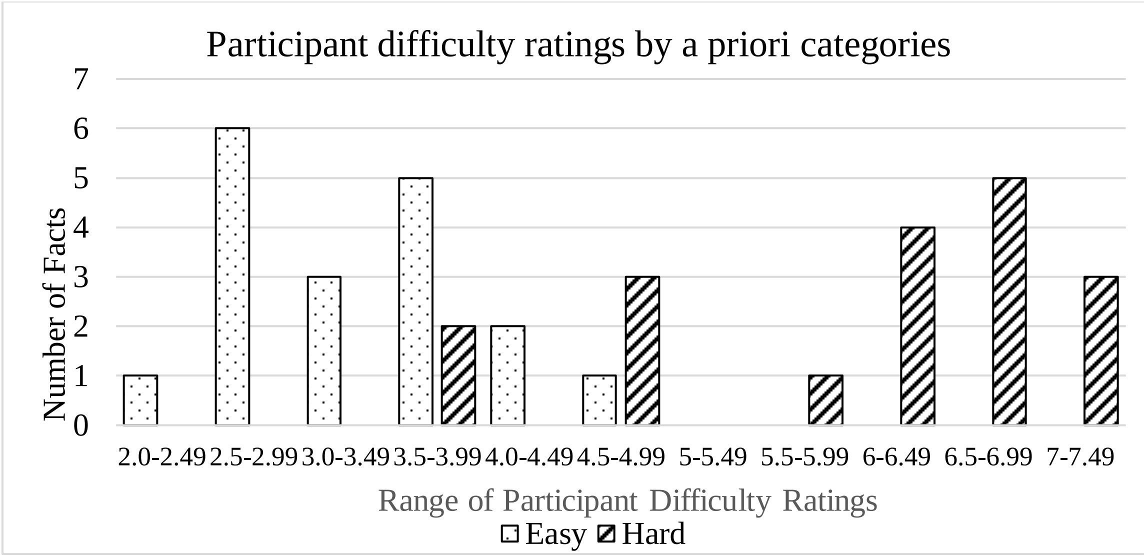

Figure 13. *Difficulty rating distribution for the 36 facts. Facts are categorized by a priori ratings described in Chapter 2.*

Participants also generally agreed on ratings. Average ratings were calculated for each item across all participants and compared to individual ratings to determine how closely each participant's rating matched the ratings of other participants. On average, individual participant ratings were positively correlated with the average ratings for each item (r = .70). The average participant rating for hard facts (M = 6.06, SE = .15) was reliably higher than average rating for easy facts (M = 3.67, SE = .32), $t(82) = 8.22$, $p < .0001$.

Fact difficulty ratings and recall

Whether participant ratings of item difficulty were related to their recall of facts and folders was examined. For each participant, a point-biserial correlation was calculated between whether or not they correctly recalled a fact and the difficulty rating they gave for that fact. For participants in the writing condition, there was a negative correlation between difficulty rating and fact recall (r_{pb} = -.41, $p < .05$). There was no correlation between difficulty rating and folder recall. For participants in the typing condition, there was also a negative correlation between difficulty rating and fact recall (r_{pb} = -.40, $p < .05$). There was similarly no correlation between difficulty rating and folder recall.

If participants were relying on being able to use their notes for facts that were more difficult, a higher difficulty rating would have been associated with a higher proportion of participants who recalled the associated folders. Because this was not the case, it does not appear that participants were able to remember where they stored their notes if they were unable to remember the facts themselves. It is likely that participants were unable to offload memory for the harder facts by relying on their notes because they were unable to successfully associate the fact cues with the folders. The hard facts might have required too much effort to associate with folders and participants may not have been able to encode either the fact or where they stored their notes on the fact.

Recall focus

Recall focus was determined by asking participants, after they had completed the task, “what did you focus on trying to remember?” If participants did not give a clear answer or indicated they did not understand the question, the research assistant conducting the interview would clarify that s/he meant “facts or folders or both.” Participants responses were recorded by the research assistants conducting the interviews. The number of participants in each group who said they focused predominantly on facts, folders, or both is shown in *Table 9.* According to a Chi-square test of independence, participant focus was independent from how they took notes during the task, X^2 (2, N = 84) = 2.09, p = .35. More participants chose to focus on trying to remember the facts (49%) than the folders (27%) or both (24%). There was no indication that participants who typed their notes on a computer focused on trying to remember where their notes were saved. That is, there was no evidence that the use of a computer to type and save notes was associated with a higher rate of cognitive offloading. This finding stands in contrast to a conclusions drawn by Sparrow et al. (2011) that access to information technology is associated with a reliance on being able to find externally stored information rather than on internal memory storage.

Table 9. Self-reported focus by task type contingency table.

Focus / Task type	Facts	Folders	Both
Typing	24	9	11
Writing	17	14	9
Total	41	23	20

Fact and folder recall by participant focus

The proportion of facts and folders that participants recalled was examined with a 3 (Focus) x 2 (Difficulty) x 2 (Recall Content) ANOVA. Means are shown in *Figure 14.* Main effects and interactions are shown in *Table 10.* The main effects of content and difficulty and the interaction between difficulty and content were discussed earlier. There was no main effect of participant focus, but there was an interaction between participant focus and content recalled. The interaction is shown in *Figure 15.*

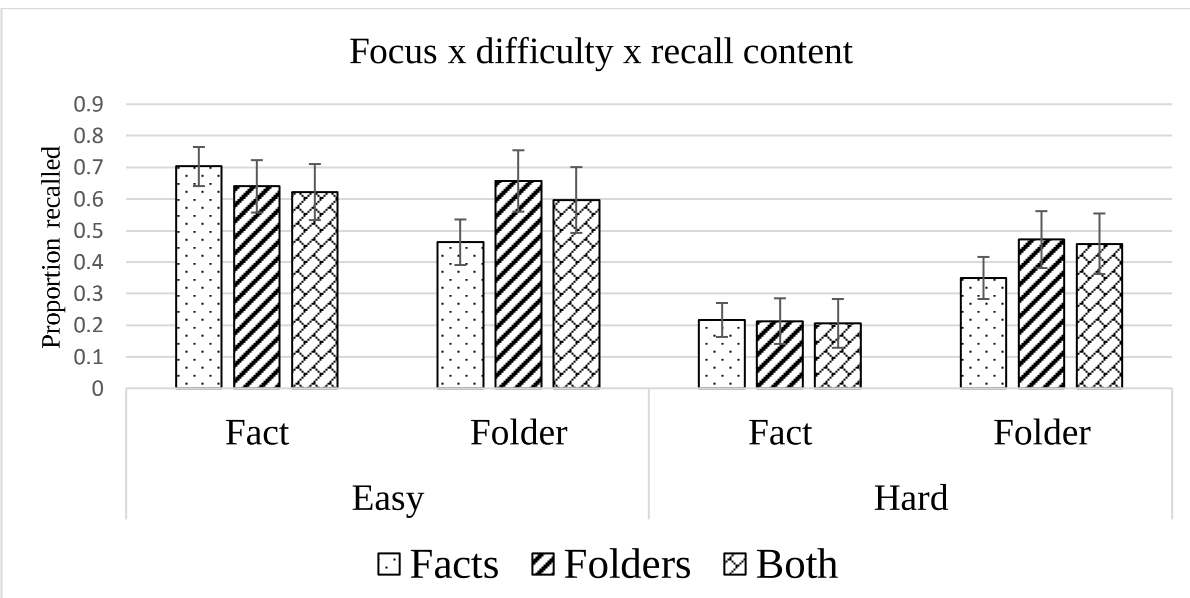

Figure 14 .Proportion of facts and folders recalled when participants reported focusing on facts, folders, or both. Error bars represent 95% confidence intervals.

Table 10. 3 (Participant focus) x 2 (Difficulty) x 2 (Recall Content) repeated measures ANOVA.

Source	SS	df	*MSE*	*F*(1,82)	*p*	Partial η^2
Participant focus	.24	2	.12	1.28	.28	.03
Difficulty	6.64	1	6.64	399.82	< .0001	.83
Content	.33	1	.33	7.16	< .01	.08
Focus x Difficulty	.01	2	.01	.30	.74	.01
Focus x Content	.69	2	.34	7.39	.001	.15
Difficulty x Content	1.69	1	1.69	115.95	< .0001	.59
Focus x Difficulty x Content	.07	2	.04	2.47	.09	.06
Error	1.18	81	.02			

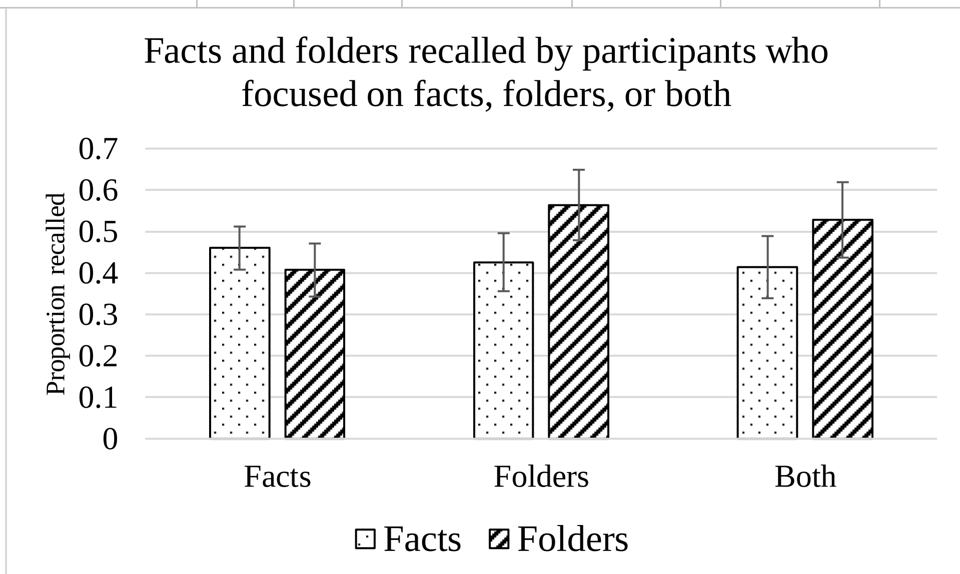

Figure 15. Interaction between participant focus and recall content. Error bars represent 95% confidence intervals.

Participants who said they focused on folders recalled more folders (*M* = .56, *SE* = .04) than facts (*M* = .43, *SE* = .04), *t*(22) = 3.84, *p* < .001. Participants who said they focused on both also recalled more folders (*M* = .53, *SE* = .05) than facts (*M* = .41, *SE* = .04), *t*(19) = 2.29, *p* = .03. This was not the case for participants who said they focused on facts. They recalled comparable rates of facts (*M* = .46, *SE* = .03) and folders (*M* = .41, *SE* = .03), *t*(40) = 1.47, *p* = .15. It seems that participants who reported focusing on remembering the facts actually ended up recalling less information overall than those who targeted folders or focused on both. If these participants were more focused on facts but could not recall those facts at a higher rate than those focused elsewhere, it may just be that some of the facts required more cognitive effort than participants were either willing or able to devote to the task.

While participants seemed to be performing similarly on fact recall regardless of self-reported focus, folder recall seems to be more dependent upon whether participants really tried to remember where they saved their notes. This result may further elucidate the effect that was found in Experiment 2 of Chapter 2 wherein participants choosing folders, i.e., participants who had their attention directed to the folders where they saved their notes, had better memory for folders than those who did not and were able to concentrate on the facts. The lack of difference in fact recall between participants who focused on facts and those who focused on folders or both, coupled with the results of Chapter 2 Experiment 2, indicates that the mere act of choosing where to store notes could impact memory for facts regardless of intended focus.

Interview data: Strategies

Interview responses were transcribed by the undergraduate research assistants who conducted the brief interviews after the test phase of the task. Research assistants were instructed to write down the gist of what a participant had said. Participant responses to the question about which strategies they used to determine where to save their notes were broadly categorized into the following: strategies that involved associating the facts and folders, strategies that associated fact difficulty and folders, and no strategy employed. The majority of participants overall (n = 56) indicated that they somehow associated the name of the folder with the fact for which they had made a note. These participants were evenly split between the writing and typing versions of the task. Overall, 13 participants indicated saving their notes based on difficulty rather than associating the facts and folders, four participants who completed the writing task and nine participants who completed the typing task indicated using this strategy. Out of the 11 participants who indicated that they had not employed a strategy to determine in which folder to save each note, seven completed the writing task and four completed the typing task.

Strategy was examined in relationship to self-reported focus. The number of participants reporting each strategy as a function of reported focus is shown in *Table 11*. A Chi-squared test of independence determined that type of strategy used (a strategy that associated the facts with the folders, the difficulty of the facts with the folders, or no reported strategy) was independent from what participants reported they had focused on trying to remember, X^2 (4, N = 84) = 5.52, p = .24. Participants who focused on the facts were just as likely to use a strategy to decide where to save each note as participants focused on folders or both. This is likely the same phenomenon that was described in Experiments 1 of Chapter 2 wherein the very act of choosing in which folder to save a note was associated with strategy usage regardless of belief about whether the notes would actually be used during the test.

Table 11. Participant strategy and self-reported focus contingency table.

Strategy **Focus**	Association	Difficulty	No Strategy/Unknown
Facts	24	7	11
Folders	18	2	2
Both	14	4	2

General Discussion

The primary question addressed in this chapter was whether participants would behave differently in regards to what information they encoded in internal memory depending on if they were taking notes by typing and saving them into a computer folder or if they were writing the notes by hand and saving them in physical folders. The answer to that question is complicated. Based on an examination of the whether there was a relationship between the type of note-taking that the participant did and what the participant chose to focus on trying to remember, it was determined that how the participant took notes during the experiment and what the participant reported focusing on trying to remember were independent of each other. Typing and saving notes on a computer did not lead participants to focus more on where they saved their notes than on the facts on which they took notes. Access to information technology, in this case, did not influence how participants approached information they were tasked with remembering.

All participants in the experiment had to choose where each note they took would be saved, which was comparable to the choice condition in Experiment 2 of Chapter 2. More participants chose to focus on the facts than did on the folders or both. The quality of notes, as measured by the proportion of idea units present in each note, was comparable between typing and writing participants for easy facts and slightly better for writing participants on hard facts. This result is a little surprising considering previous findings that typing notes was associated with more verbatim (word-for-word) note-taking (e.g., Aragón- Mendizábal et al., 2016; Mueller & Oppenheimer, 2013). Participants who took notes by hand performed marginally better on both fact and folder recall. This may have been partly due to amount of time it took to write notes by hand and to physically place a note-card in a particular folder.

The information that participants reported focusing on trying to recall led to some interesting effects. Participants who said they focused on folders or both facts and folders recalled more folders than facts. They also recalled more folders than the participants who said they focused on remembering the facts. What is interesting is that participants who said they focused on remembering the facts did not remember more facts than participants in the other two groups. The only difference between them is that they recalled fewer folders. In theory, by expending less mental effort on trying to remember the folders, they should have been able to expend some more effort on recalling the facts. In practice, it is likely that they still had to think about the folders because they were tasked with evenly distributing their notes, but they did not get the added benefit of remembering where they saved their notes.

Fact difficulty was a variable in the current experiment and in the experiments in Chapter 2. In all experiments, there was a main effect of difficulty and a difficulty-by-content interaction in which folder memory was lower than fact memory for easy facts but the reverse was true for hard facts. The participant provided difficulty ratings obtained in the current experiment validated the difficulty ratings of the facts used in both experiments of Chapter 2. The hard facts were rated as harder and the easy facts were rated as easier.

The focus of this experiment was on the encoding aspect of note-taking in that participants were not allowed to study their notes before being tested on the facts that they studied. Writing notes by hand seemed to benefit the encoding process a bit more than typing notes on a computer and note quality seems to have been fairly comparable between participants who wrote and participants who typed. While overall the results might be in favor of taking notes by hand, the participants who typed their notes did not seem to engage in more cognitive offloading than their writing counterparts. The current results suggest that the phenomenon described by Sparrow, Liu, and Wegner (2011), in which participants remembered more of where information was saved rather than what the information was, may not be as pervasive and problematic has been suggested.

One of the primary challenges faced in conducting this experiment was trying to make the experience of participants who did both types of tasks as equal as possible. Participants who competed the writing task took a longer time to get through the study phase. The task was self-paced and, because the stimuli were delivered verbally, all stimuli were delivered at the same rate regardless of how long it took individual participants to take notes. Participants were allowed to take notes as the facts were played, which may have given an advantage to participants in the typing condition who could take notes faster than the participants who took notes by hand, but this advantage did not translate into better recall for participants in the typing group. Participants who completed the writing task were more advantaged in recalling the names of the folders where they stored their notes because they interacted more directly with the folders and, along with visual memory for their placement, they also had spatial information that they could use to improve memory. Participants in the typing task saw a list of folder names on a screen that had a spatial structure (they were read from top to bottom), but the physical act of placing a note-card in a folder that is either closer or further away likely gave participants in the writing task access to additional cues that were not available to participants who typed their notes.

Future research could further explore the boundaries of cognitive offloading in note-taking by creating a more ecologically valid experiment in which participants name their own folders rather than using pre-existing folders named after colors of the rainbow. In order to investigate whether or not participants offloaded their memory for facts onto their notes with the expectation of being able to use them, future research might examine recall for facts when participants are given access to the notes they could locate.

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CHAPTER 5: SUMMARY AND CONCLUSIONS

Summary

The purpose of this dissertation was to examine the relationship between the externalization of memory through note-taking and what is encoded in internal memory. A summary of the findings as well as how each Chapter fit together is shown in *Figure 16.*

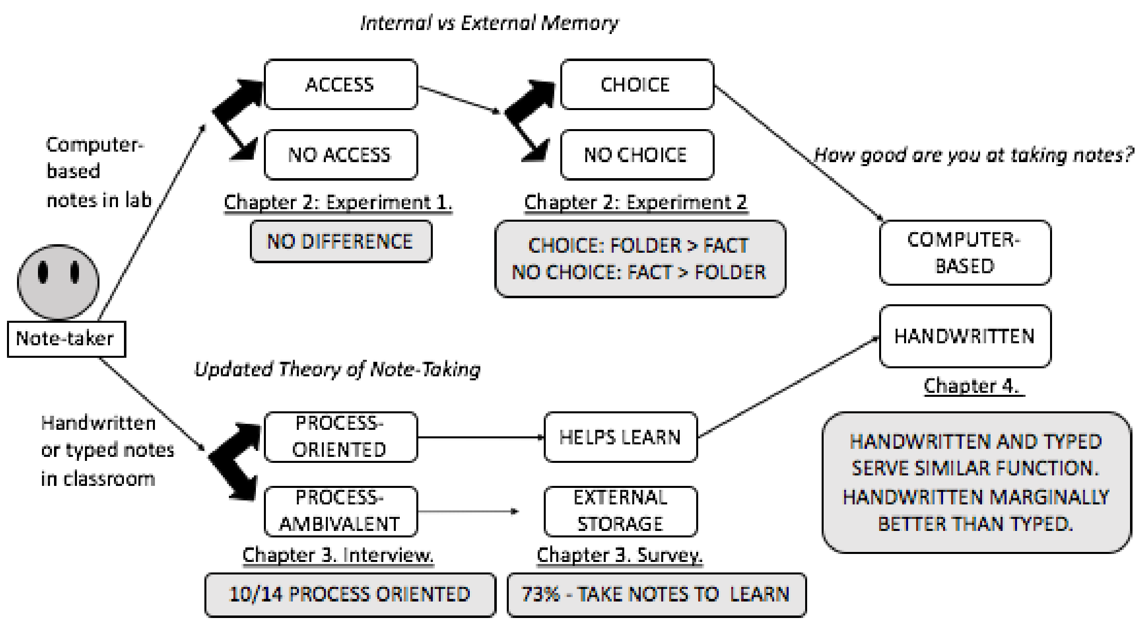

Figure 16. Summary of findings.

In Experiment 1 of Chapter 2, participants listened to 36 facts of variable difficulty and typed notes on each fact into a computer. After typing each note, participants had to choose one of six folders named after the colors of the rainbow, in which to save the note. Half of the participants were told they would be able to use their notes during a test on the facts if they could remember in which folder they saved the relevant note. The remaining participants completed the same task but were told they would not be able to use their notes during the test. Participants were then tested using a cued recall test for the facts as well as the names of the folders where they stored their notes for each fact. Regardless of what participants were lead to believe about using their notes, participants in both groups behaved similarly and had similar rates of recall for the facts and the names of the folders. When they were asked to describe the strategies that they used to determine in which folder each note would be saved, the majority of participants in both groups described using strategies that would help them associate the names of the folders with the facts saved within them.

Participant note quality was also examined to determine whether those who believed they would be able to use their notes during the test wrote better notes than those who were told they would not be able to use their notes. Note quality was scored on a binary basis based on whether the notes would have provided the participant with all of the information they needed to correctly recreate the relevant fact during the test. Participants in both groups had comparable notes. Fewer than half of the notes for hard facts were rated as good notes to have during the test. The similar behavior of participants in terms of note quality as well as recall was further investigated.

It seemed that participants were putting some mental effort into trying to remember the folders associated with each fact regardless of if they were told they would be able to use their notes during the test. It was posited that participants in both groups behaved in a similar fashion because they were doing the same task. All participants had their attention directed to the folders when they had to pick where to save the notes for each fact. A second experiment was conducted to determine whether the act of choosing where to save notes was driving memory for folders and if memory for folders might have been competing with memory for facts as would be expected in the context of a limited working memory capacity.

Experiment 2 of Chapter 2 examined the effect that choosing where to save notes had on memory for facts and folders. Participants performed the same task as in Experiment 1, but with a few changes. The overall low quality of notes for hard facts illustrated a difficulty that participants were having with understanding the stimuli that they were hearing. In order to reduce the impact of audio quality on recall, all stimuli were re-recorded for Experiment 2 in a clearer voice that spoke slower. In order to determine whether the act of choosing folders affected memory for facts and folders, half of participants in Experiment 2 had to choose in which folders to save their notes while the remaining participants had their notes randomly assigned to folders. An additional manipulation was included to examine whether participants would choose to rely on internal memory for facts that were easy and external memory for facts that were hard. Participants who had to choose where to save their notes were only allowed to save 24 out of 36 notes. They were informed in advance that they would only be allowed to save 24 notes and were provided with a counter of how many saves they had left each time they had to choose where to save their notes. Participants who did not get to choose where their notes were saved were each matched with a participant in the choice group such that the same facts that one participant in the choice group chose not to save were also not saved for one participant in the no choice group. That way comparisons could be made between the two groups without the potential confound of fact difficulty which would be present if participants in the choice group did not save only easy facts and participants in the no choice group had folders randomly assigned.

The results of Experiment 2 revealed that the act of choosing in which folder to save each note led to better recall for folders and worse recall for facts than having notes randomly assigned to folders. Participants who chose where to save their notes had their attention directed to the folders and seemingly behaved in a similar fashion to the participants in Experiment 1. Participants who did not choose where to save their notes did not devote much effort to encoding the folders alongside the facts and ended up having better recall for facts than their folder choosing counterparts. Note quality was again examined but instead of simply rating notes as good or poor as in Experiment 1, notes were rated according to the proportion of idea units present. Participants who did not choose where to save their notes had notes of comparable quality for both saved and not saved notes. Interestingly, participants who chose where to save their notes had significantly lower quality notes for the facts they chose not to save. It is likely that these participants made the decision about whether or not to save their notes either before or as they were typing them. This may have detracted from their ability to encode the facts.

Both Experiments in Chapter 2 were based on the assumption that the act of taking notes contributes to encoding. The focus of the experiments was on the encoding hypothesis of note-taking, which says that the primary learning benefit of note-taking comes from the process itself (Di Vesta and Gray, 1972). Participants were not allowed to study their notes so they instead had to rely on the process of note-taking as a way to learn the information they were hearing, even though they were told otherwise. In order to determine the ecological validity of listening to facts and taking notes, a qualitative study was conducted in which undergraduate students were interviewed about their note-taking habits. Chapter 3 describes the findings of structured interviews in which students were asked about their purpose for taking notes, how they use their notes, and how technology has impacted their note-taking. Chapter 3 also includes the results of a survey that was created based on the themes that emerged from the interviews and distributed to a much larger sample of students. The primary findings of Chapter 3 were that most of the interviewed students found the process of note-taking to be useful either in paying attention in class or in helping them learn the materials. Most of the interviewed participants also indicated that they altered their note-taking habits based on the online availability of lecture-slides. The survey confirmed that the majority of respondents found the process of taking notes helpful. It also indicated that the majority of respondents generally take notes by hand.

One of the goals of Chapter 3 was to determine whether students took different approaches to note-taking when they wrote their notes by hand compared to when taking notes on a computer. Most of the respondents took notes by hand and many said they tried taking notes on a laptop but either found it distracting or had another issue that prevented them from using a laptop regularly. The purpose of Chapter 4 was to make a direct comparison between handwritten and typed notes in terms of willingness to rely on external memory as well as what information is encoded internally. In order to do so, two tasks were created that were largely the same as the tasks completed by participants in Chapter 2. In the typing version of the task, participants listened to 36 facts and after each fact typed a note. This condition was identical to the choice condition of Experiment 2 except that participants were allowed to save all notes and participants took notes as they were listening to the facts rather than afterwards. The writing version of the task involved listening to 36 facts and taking notes by writing on a notecard. Participants could take notes while listening to the facts. Participants then had to place the notecard with their notes on it in a labeled folder that was hanging from a folder stand. The folders had the same labels, the colors of the rainbow, as the ones on the computer. All participants additionally had to give difficulty ratings for each of the facts that they heard.

The results of Chapter 4 indicated that participants did not base their cognitive offloading behavior on how they were doing the task. Participants did not focus on remembering where to find their notes if they typed them and participants did not focus on the facts themselves if they wrote them. Participant's self-reported focus was independent of how they took notes during the study phase. Their focus may have impacted what they were actually able to recall during the test. Participants who said they focused on facts surprisingly did not recall more facts than participants who said they focused on folders or both. They did, however, remember fewer folders than participants who focused on either folders or both facts and folders. It seems that the act of choosing where to save notes may disrupt encoding of facts regardless of whether one chooses to focus on the facts. Overall participants recalled more information when they took notes by hand and saved them in physical folders. This was likely because participants who took notes by hand spent more time writing the notes and more time physically putting the notes into the folders than participants who simply typed the notes and pressed a key to indicate where to save them. No strong conclusions could be drawn about the difference between handwritten and typed notes in terms of cognitive offloading. Some of the students who were interviewed in Chapter 3 indicated that the motor act of taking notes by hand helped them remember information, but if this effect was present in Chapter 4 it was very small and could not be disentangled from the time spent doing the task.

Conclusions

Several theoretical frameworks were described in the introduction to this dissertation. Memory and depth of processing were addressed in Chapters 2 and 4. Recall tends to be better for information that is processed semantically, particularly if that processing involves making connections between the facts and information that was already in memory (e.g., Craik & Lockhart, 1972; Craik & Tulving, 1975). Participants memory for facts and the folders where they saved notes on the facts were tested. In Experiment 2 of Chapter 2 it was found that participants who got to choose whether or not to save each note wrote lower quality notes when they were not going to save them. They also had worse recall for facts that were not saved. The act of note-taking may have led to deeper processing of the information than would have occurred if notes were not taken, which meant worse recall for facts for which notes were either not taken or were missing information. The same could have been occurring with the strategies that they used to connect facts with folders. In both studies of Chapter 2 participants who chose where to store their notes had better recall for folders than participants who did not regardless of whether they believed they would be able to use them. Most participants described using strategies to connect facts and folders, which likely entailed a deeper level of processing. In Chapter 3, many of the students who were interviewed indicated that taking notes helps them to process information and to remember it better. A direct comparison between handwritten and typed notes was made in Chapter 4 and when the facts were hard, note quality was better for participants who were taking handwritten notes. Memory for hard facts was also slightly better for participants who took handwritten notes. Mueller and Oppenheimer (2013) found that typing notes led to worse recall than handwriting them and argued that typing was a more mindless form of note-taking. Instead of having to recreate each individual letter, typing entails simply pressing on a key that is identical in shape to other keys which represent different letters (Kiefer & Velay, 2016). Participants in the writing condition of Chapter 4 spent more time taking notes, which gave them more time to process the information they were writing down, likely leading to better recall.

The rationale for comparing between memory for facts and memory for folders in Chapters 2 and 4 was that because working memory has a limited capacity (Shiffrin, 1993), the two types of information were in direct competition with each other. This effect was most evident in Experiment 2 of Chapter 2 in which participants who had to choose where to save their notes had better memory for folders and worse memory for facts that participants who did not make that choice, likely because they were thinking about whether or where to save their notes as they were taking them.

Throughout the dissertation, note-taking was also examined through the lens of how it contributes to learning. The experiments in Chapters 2 and 4 dealt predominantly with the encoding hypothesis of note-taking, which posits that the memory benefit of note-taking is derived from the act of note-taking itself (Di Vesta & Gray, 1972). In all three of the experiments described in the two chapters, participants took notes but were not allowed to study them before being tested on the materials they studied. A goal of Chapter 4 was to determine whether participants took different approaches towards handwritten and typed notes and if writing was used more as a process while typing was used as an external memory store. How participants wrote their notes (with a pen or on a keyboard) was found to be independent of what participants reported they focused on trying to remember. No evidence was found that those who wrote their notes focused on the encoding benefit of note-taking while those who typed their notes focused on remembering where they put them so they could use them later. The external storage hypothesis, that note-taking benefits learning because it creates a stable external record that can be studied was addressed in Chapter 3. Ten out of the 14 students who were interviewed said they were process-oriented and derived a benefit from the act of taking notes, but the remaining four did not indicate that they relied on their notes for external memory storage.

Metacognitive strategies were examined in each chapter. In Chapters 2 and 4, participants were given the opportunity to offload their internal memory onto the notes they were taking. Except for half of the participants in Experiment 1 of Chapter 2, all participants were told they would be able to use their notes during a memory test if they could remember where individual notes were saved. The interaction between fact difficulty and what information participants recalled that was found in both experiments of Chapter 2 as well as in Chapter 4 indicated that when facts were hard to remember, participants remembered more folders than facts. It could be that they tried to remember the folders because they had more confidence in their notes than in their memories for the facts. Ferguson, Mclean and Risko (2015) found that participants were willing to rely on an external source of information like the internet when they were less confident in their own internal knowledge. Maybe participants in the experiments described in Chapters 2 and 4 were similarly willing to rely on their notes instead of their memories. It could also be that participants were reluctant to engage in the more effortful processing that was required to remember the hard facts because humans are cognitive misers (e.g., Kahneman, 2011; Stanovich, 2009). The dual-process theory of higher cognition, that there are two types of mental processes, one of which is more effortful and thereby less appealing than the other, could not adequately explain the results of Chapters 2 and 4. If people are reluctant to engage in effortful mental processing, it would not make sense to remember folders alongside facts when the facts are easy and there is no need to remember where the notes are because the notes are not needed. With the exception of the participants who did not choose where to save their notes, most participants remembered easy folders alongside the facts. The soft constraints hypothesis, that people try to minimize the performance costs of doing a particular task while still achieving the goal of the task, may explain why participants were remembering folders alongside easy facts. Participants who did not get to choose where to save their notes remembered fewer folders alongside easy facts than participants who did choose, indicating that the act of choosing the folders led to improved memory for folders regardless of whether the notes would actually be needed during the test. When describing their strategies, many participants in the experiments of Chapters 2 and 4 indicated that they tried to associate the facts with the folders when choosing where to save their notes. The process of encoding the folders was tied into the process of choosing where to save their notes, which was a requisite part of the task they were doing. By relating the facts to categories or colors in order to remember the names of the folders, participants could have been encoding the folders alongside the facts. The easy facts made it possible to do so by not requiring a lot of processing in order to parse. The hard facts might have taken more mental effort because they contained unfamiliar terms that had to be interpreted within the context of the other information in the fact in order to be understood. The extra effort would likely have made it more difficult to encode the folders as well because in order to associate a fact with a category or the name of a folder, one first had to understand the fact well enough to know in which category it might fit. Participants ability to recall folders in Chapters 2 and 4 may also have reflected their willingness of offload cognition. Cognitive offloading is the use of physical actions, either through interaction with an external device or through body movement, to reduce the cognitive demand of a particular task (for review, see Risko & Gilbert, 2016). Participants in the experiments of Chapters 2 and 4 could have been offloading their memory for facts onto their notes and then remembering in which folder the notes were saved in order to use them. The intent to offload was most evidence among participants in Experiment 2 of Chapter 2 who were tasked with choosing which notes they would save. They had lower quality notes for the notes they did not save than for the notes that they did, which might have been a result of not willing to put in the effort of taking good notes when they could not be used to offload memory for facts. Students who were interviewed in Chapter 3 also brought up cognitive offloading when talking about the availability of lecture slides online. Many of the interview respondents described taking fewer or less detailed notes when slides were made available. They seemingly offloaded the mental process involved in writing down detailed notes to the lecture slides which were made available for them to study. Haynes McCarley, and Williams (2015) examined the notes that students took in a lecture class in which PowerPoint slides were used to present the lectures and found that notes taken during PowerPoint presentations contained less relevant information than what was available on the slides. If the process of note-taking itself leads to better memory, the availability of lecture slides may have a negative effect on learning outcomes (e.g., Worthington & Levasseur, 2015).

Over the course of three laboratory experiments and a qualitative study, the relationship between note-taking and memory, and how technology may affect that relationship, was examined. The reliance on information technology instead of internal memory initially described by Sparrow, Liu, and Wegner (2011) was not replicated, but the methods utilized in the experiments described in Chapters 2 and 4 were not the same as those employed by Sparrow and colleagues. Participants in Chapters 2 and 4 listened to facts and took notes instead of reading and typing them into a computer like the participants in a couple of experiments conducted by Sparrow and colleagues. This more closely reflected how students behave in the classroom. Sparrow and colleagues also used a within-subjects design to compare memory for facts that were saved on a computer and facts that were not. Their facts were also randomly assigned to folders, which was also experienced by one group of participants in Experiment 2 of Chapter 2. When participants did not get to choose in which folders to save their notes, they had much worse recall for folders, which is not what was found in the Sparrow study. It is likely that participants in the Sparrow study had an easier time recalling folders than facts because the memory task associated with recalling folders was easier (cued recall instead of free recall). Some evidence of offloading was found, but it could have been due to the difficulty of the facts being learned rather than a willingness to rely on the notes that were saved on the computer. In Chapter 4 the information that participants reported trying to remember was independent from how they took notes so people might not be more willing to rely on using their notes when they type them than when they write them by hand.

Note-taking is still an important process that can contribute to learning. The process-oriented group of respondents described in Chapter 3 as well as the majority of survey respondents who found the process of note-taking helpful for paying attention in class as well as for learning during class provide evidence that technology has not fundamentally altered the function of note-taking. Participants who typed their notes did not have meaningfully worse recall for facts than participants who wrote their notes and the small difference between the two groups could have been explained by the longer time that participants who wrote their notes by hand spent on the task. While laptops may be distracting when used in classrooms in which technology is not integrated into the curriculum (e.g., Fried, 2008; Ragan, Jennings, Massey, & Doolittle, 2014; Ravizza, Uitvlugt, & Fenn, 2017), some of the students interviewed in Chapter 4 recognized that distraction and avoided using laptops for that reason. Instructors should be more concerned about the effect of posting lecture slides online on student note-taking habits. The encoding aspect of the note-taking process was shown to be important in Chapter 2 Experiment 2 when participants had worse recall for notes that they did not save which were of lower quality and either included less information than was given in the fact or no information at all. The importance of the encoding aspect was also highlighted in Chapter 3 among the process-oriented group of interview respondents as well as among survey respondents.

Future Work

The present laboratory studies used a fairly contrived paradigm in which individual notes were saved in pre-existing folders that were named after the colors of the rainbow. When students save notes on their computers they likely save them in folders that they have created and named in a way that would make sense for them. Future work could examine note-taking and the reliance on being able to find externally stored information in a more realistic situation. Participants could be tasked with naming their own folders in which to store their notes. It would also be interesting to examine participant recall performance if they were actually allowed to use their notes if they could remember where they were saved. The relationship between the availability of lectures slides online and how students approach the note-taking process could be further examined in a controlled laboratory study in which participants take notes on either a lecture for which the slides will be made available for them or a lecture for which slides will not. Also, because text-based search tools can be used to avoid encoding storage location at all, an exploration of how participants' recall is influenced if all notes are stored in the same place, but search is enabled. Willson & Given (2014) categorized students' search behavior into three categories, for example, and Sharit, Taha, Berkowsky, Profita, & Czaja (2015) found that search accuracy was influenced by cognitive abilities.

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APPENDIX A: IDEA UNITS

Table 1. Easy and Hard Facts with Recall Cues and Idea-units used in Chapter 2. Experiment 1 and 2.

HARD		
Statement	**Recall Cue**	**Idea-units**
1. Signal detection theory quantifies the ability to distinguish signal from noise.	Signal detection theory	Quantified. Ability. Distinguish signal from noise.
2. A furlong is a measure of distance equal to 220 yards.	Furlong	Equal to 220 yards.
3. The prime minister of Canada is appointed by the governor general on behalf of the monarch.	Canada	Prime minister. Appointed by governor general. On behalf of monarch.
4. The Northern flicker is the state bird of Alabama.	Northern flicker	State bird. Alabama.
5. Numismatics is the study or collection of currency.	Numismatics	Study or collection. Currency.
6. Quantitative genetics is a branch that deals with phenotypes that vary continuously.	Quantitative genetics	Phenotypes. Vary continuously.
7. Hermeneutics is the theory and methodology of text interpretation.	Hermeneutics	Theory. Methodology. Text interpretation.
8. Electrolysis is a technique that drives otherwise non-spontaneous chemical reactions.	Electrolysis	Drives. Non-spontaneous. Reactions.
9. Metcalfe's law allows you to calculate the value of a telecommunications system.	Metcalfe's law	Allows. Calculate. Value of telecommunications system.
10. URL stands for uniform resource locator.	URL	Uniform. Resource. Locator.
11. Brady disclosure consists of evidence that is relevant to the guilt or innocence of a defendant.	Brady disclosure	Evidence. Relevant to guilt or innocence.
12. Gamma spectroscopy is the study of the energetic transitions in atomic nuclei.	Gamma spectroscopy	Study of. Energetic transitions. Atomic nuclei.
13. Parkinson's disease involves major loss of dopaminergic cells in the substantia nigra.	Substantia nigra	Parkinson's disease. Major loss. Dopaminergic cells.
14. Tardive dyskinesia is characterized by repetitive, involuntary, purposeless movements.	Tardive dyskinesia	Repetitive/involuntary/purposeless. Movements.
15. Korsakoff's syndrome occurs as a result of thiamine deficiency.	Korsakoff's syndrome	Occurs as a result. Thiamine deficiency.

Table 1. (continued)

Statement	**Recall Cue**	**Idea-units**
16. In the endothermic process, the system absorbs energy from its surroundings usually in the form of heat.	Endothermic process	System. Absorbs energy. Heat.
17. Mass spectrometry is a technique that helps identify the amount of chemicals present in a sample.	Mass spectrometry	Identify. Amount of chemicals. In sample.
18. Thermal ionization is the process by which atoms are spontaneously ionized from a hot surface.	Thermal ionization	Atoms. Spontaneously ionized. Hot surface.
	EASY	
Statement	**Recall Cue**	**Idea-units**
19. The collective term for a group of owls is a parliament.	Owls	Parliament.
20. The collective term for a group of alligators is a congregation.	Alligators	Congregation.
21. Al Capone's business card said he was a used furniture dealer.	Al Capone	Business card. Furniture dealer.
22. The king of hearts is the only king without a mustache.	King of hearts	Only king. No mustache.
23. Every year about 98% of the atoms in your body are replaced.	Atoms	98% atoms. Replaced each year. Body.
24. Elephants are the only mammals that can't jump.	Elephants	Only mammal. Can't jump.
25. A lion's roar can be heard from 5 miles away.	Lions	Roar heard. 5mi away.
26. The Baby Ruth candy bar was actually named after Grover Cleveland's baby daughter, Ruth.	Baby Ruth	Named after. Grover Cleveland's daughter.
27. Minus 40 degrees Celsius is exactly the same as minus 40 degrees Fahrenheit.	Temperature	-40deg equal.
28. The great Pyramids of Giza are the only one of the Seven Wonders of the Ancient World that still exist.	Pyramids	Only wonder. Still exists.
29. The Atlantic ocean is more salty than the pacific ocean.	Atlantic ocean	Saltier than. Pacific.
30. A person will shed over 40 pounds of skin in their lifetime.	Skin	Shed. Over 40lb. In lifetime.

Table 1. (continued)

Statement	**Recall Cue**	**Idea-unit**
31. Only two countries border three oceans, the United States and Canada.	The US and Canada	Only countries. Border 3 oceans.
32. Damascus is the oldest continuously inhabited city in the world.	Damascus	Oldest. Continuously inhabited city.
33. Every continent in the world contains a city called Rome.	Rome	Every continent. Has city called.
34. North Dakota is the only state that has never had an earthquake.	North Dakota	Only state. No earthquake.
35. Poison oak and poison ivy are members of the cashew family.	Poison oak	Member of. Cashew family.
36. The giraffe has the highest blood pressure of any animal.	Giraffe	Highest blood pressure.

APPENDIX B: SCREENSHOTS OF PROCEDURE

On-screen prompts that were provided for participants in Experiment 1 of Chapter 2.

Type in a version of the sentence that you heard as if you were taking notes in class.
Hit "enter" when you are finished.

In which folder would you like to save the notes you just typed?
The number next to the color indicates the number of notes already stored in that folder.
1 = RED (1)
2 = ORANGE (2)
3 = YELLOW (1)
4 = GREEN (3)
5 = BLUE (1)
6 = PURPLE (0)

Your entry was saved to the GREEN folder.

APPENDIX C: INTERVIEW PROTOCOL

Semi-structured interview protocol used in Chapter 3.

The following is a list of questions that may be asked during the course of an interview. Exact wording may change in accordance what makes sense in the context of the interview. This list is meant to cover as many areas of inquiry as have been considered prior to any data collection. The way interviews are conducted may change over time if some of the questions seem redundant or like they are not useful for answering the research questions.

How do you take notes in class?

Why do you take notes in this way?

How do you think this has affected you?

What do you think of handwritten notes?

What do you think of notes typed on a laptop?

Do you bring your laptop to class?

How do you think taking notes on a laptop compares to taking notes by hand?

What do you think of other people using their laptops during class?

What kind of information do you take notes on? Why?

What information do you leave out? Why?

How do you organize your notes?

What do you do with your notes after?

Do you use your notes to study?

How do you find the notes you need?

How do you think note-taking in this way impacts your memory? The way you learn? What you pay attention to in class?

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Not all of the above questions will be asked and some questions may be asked that are not listed if there are relevant follow-up questions that have not yet been considered.
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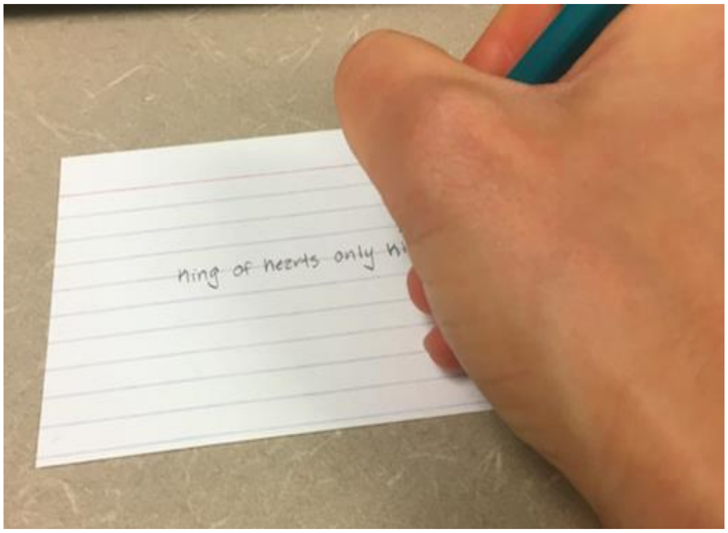
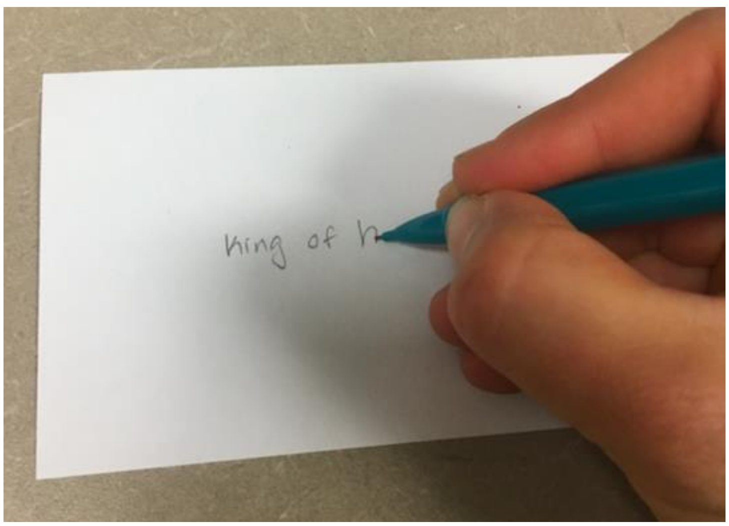
APPENDIX D: PHOTOS OF PROCEDURE

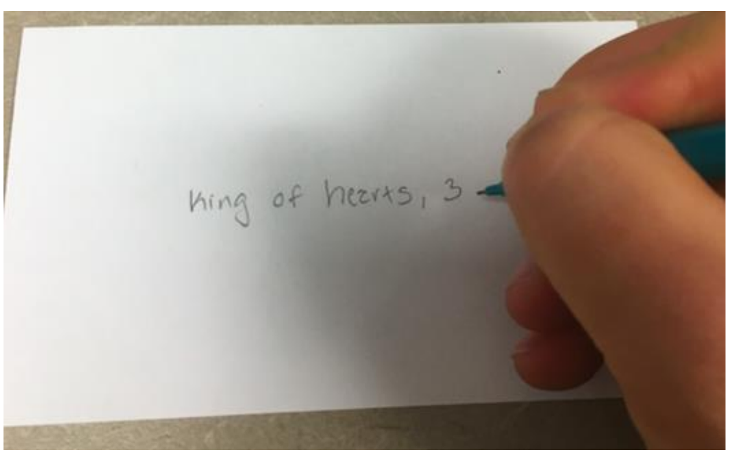
The procedure for the writing task described in Chapter 4.



1.Participants listened to a fact and wrote a note. Participants were allowed to write notes as they listened to each fact and did not have to wait for the entire fact to play before they began writing.



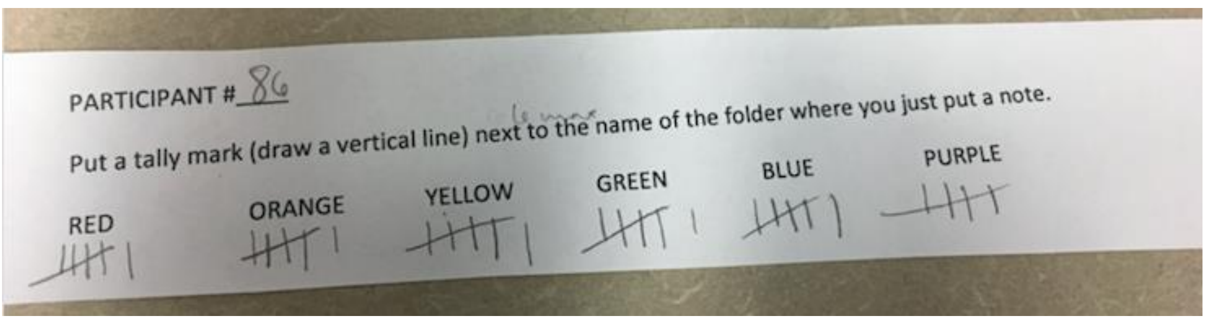
2. Once the participants had written a note, they were instructed to flip the note-card and write the cue, which was provided for them on the computer screen, on the other side of the card.



3. After writing the cue on the back of the card, participants were instructed to provide a difficulty rating, on a scale from 1-10, for the fact they had just heard.

4a. Participants were then directed to select a folder among the six identical folders that were in a folder organizer next to the computer screen. Each folder had a label with the name of a color corresponding to the colors of the rainbow.

4b. Participants placed the note-card in the folder of their choice.



5. Participants were then instructed to make a tally mark under the name of the folder where they had just placed a note. The example shown here is a tally sheet taken from a participant after the task was completed. Note that the participant wrote a note to remind him or herself that each folder could have a maximum of 6 notes.

APPENDIX E: IDEA UNITS AND SCORING RULES

Table 2. Easy and Hard Facts with Idea Units and Rules for Scoring. Used in Chapter 4.

#	Statement	Idea Units	Rule
1	Signal detection theory quantifies the ability to distinguish signal from noise.	Ability to distinguish. Signal from noise.	
2	A furlong is a measure of distance equal to 220 yards.	220 yards.	No approximations.
3	The prime minister of Canada is appointed by the governor general on behalf of the monarch.	Prime minister. Appointed. Monarch.	The important thing is that the Canadian PM is appointed on behalf of the monarch.
4	The Northern flicker is the state bird of Alabama.	State bird. Alabama	
5	Numismatics is the study or collection of currency.	Study/collection. Currency.	Study or collection can be mentioned.
6	Quantitative genetics is a branch that deals with phenotypes that vary continuously.	Phenotypes. Vary continuously.	
7	Hermeneutics is the theory and methodology of text interpretation.	Theory/methodology. Text interpretation.	Theory or methodology can be mentioned. Text interpretation is important.
8	Electrolysis is a technique that drives otherwise non-spontaneous chemical reactions.	Drives reactions. Non-spontaneous.	The important bit is that the reactions that are being driven would not otherwise occur.
9	Metcalfe's law allows you to calculate the value of a telecommunications system.	Calculate value. Telecommunications system.	
10	URL stands for uniform resource locator.	Uniform. Resource. Locator.	
11	Brady disclosure consists of evidence that is relevant to the guilt or innocence of a defendant.	Evidence. Guilt/innocence. Defendant.	Guilt or innocence can be mentioned. Evidence and defendant are key.
12	Gamma spectroscopy is the study of the energetic transitions in atomic nuclei.	Energetic transitions. Atomic nuclei.	
13	Parkinson's disease involves major loss of dopaminergic cells in the substantia nigra.	Loss of. Cells. Parkinson's disease.	What's important is the loss of cells related to Parkinson's disease.

Table 2. (continued)

#	**Statement**	**Idea Units**	**Rule**
14	Tardive dyskinesia is characterized by repetitive, involuntary, purposeless movements.	Repetitive/ involuntary/ purposeless. Movements.	
15	Korsakoff's syndrome occurs as a result of thiamine deficiency.	Occurs because of. Thiamine deficiency.	Vitamin is ok instead of thiamine.
16	In the endothermic process the system absorbs energy from its surroundings usually in the form of heat.	Absorbs. Heat/energy.	The important thing is that heat/energy is going into the system.
17	Mass spectrometry is a technique that helps identify the amount of chemicals in a sample.	Identify. Chemicals.	The important thing is that mass spectrometry deals with the amount of chemicals in something.
18	Thermal ionization is the process by which atoms are spontaneously ionized from a hot surface.	Atoms. Ionized. Hot surface.	
19	The collective term for a group of owls is a parliament.	Parliament.	
20	The collective term for a group of alligators is a congregation.	Congregation.	
21	Al Capone's business card said he was a used furniture dealer.	Business card. Used furniture.	
22	The king of hearts is the only king without a mustache.	Only king. No mustache.	
23	Every year about 98% of the atoms in your body are replaced.	Every year. 98% body atoms. Replaced.	The amount can be anything around 98% but it's important that body and yearly are included.
24	Elephants are the only mammals that can't jump.	Only mammal. Can't jump.	Mammal is important because elephants are not the only animal that can't jump.
25	A lion's roar can be heard from 5 miles away.	Roar. Heard. 5mi away.	

Table 2. (continued)

#	**Statement**	**Idea Units**	**Rule**
26	The Baby Ruth candy bad was actually named after Grover Cleveland's baby daughter Ruth.	Named after. Daughter.	Whose daughter is not important.
27	Minus 40 degrees Celsius is exactly the same as minus 40 degrees Fahrenheit.	-40C is equal to -40F.	
28	The great pyramids of Giza are the only one of the Seven Wonders of the Ancient World that still exist.	Only wonder. Still exist.	
29	The Atlantic ocean is more salty than the Pacific ocean.	Saltier than. Pacific.	
30	A person will shed over 40 pounds of skin in their lifetime.	Shed. Over 40 pounds. In lifetime.	
31	Only two countries border three oceans, the United States and Canada.	Only countries. Border three oceans.	
32	Damascus is the oldest continuously inhabited city in the world.	Oldest. Continuously inhabited.	Anything like continuously inhabited is acceptable.
33	Every continent in the world contains a city called Rome.	Every continent. Has Rome.	
34	North Dakota is the only state that has never had an earthquake.	Only state. No earthquake.	
35	Poison oak and poison ivy are members of the cashew family.	Cashew family.	
36	The giraffe has the highest blood pressure of any animal.	Highest blood pressure.	

APPENDIX F: IRB APPROVALS

The IRB approval letters for the experiments conducted in Chapters 2 and 4 and the interviews described in Chapter 3.

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 10/27/2016

To: Anna Slavina
W112 Lagomarcino Hall

CC: Dr. Veronica Dark
W112 Lagomarcino Hall

From: Office for Responsible Research

Title: External vs Internal Memory

IRB ID: 16-023

Approval Date: 10/26/2016 **Date for Continuing Review:** 2/23/2018

Submission Type: Modification **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 202 Kingland, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date:	12/6/2017		
To:	Dr. Stephen B Gilbert 1620 Howe Hall	**CC:**	Anna Slavina W112 Lagomarcino Hall
From:	Office for Responsible Research		
Title:	Note Taking Study		
IRB ID:	17-453		
Approval Date:	12/5/2017	**Date for Continuing Review:**	10/2/2018
Submission Type:	Modification	**Review Type:**	Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

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